2nd FLOOR MAY 28 '47

The Journal of

THE ROYAL AERONAUTICAL SOCIETY

MAY 1947 NO. 437 VOL. 51

FLY

VIKINGS TO EUROPE

BEA Vikings, Britain's most famous twin-engined airliners, now speed the regular services between London and Copenhagen, Gibraltar, Madrid, Oslo, Prague and Stockholm. Sister aircraft to those chosen to form the 'King's Flight,' they will reduce flying times while adding immeasurably to flying comfort. Month by month, more Vikings will be coming into service until all BEA routes between London and the continent are Viking routes

BEA

THE KEY TO EUROPE

BEA

British European Airways. **Reservations and enquiries through all principal travel agents or from Airways Terminal Telephone: Victoria 2323 Headquarters Northolt Middlesex**

Stuarts

THE ROYAL AERONAUTICAL SOCIETY
4 HAMILTON PLACE, PICCADILLY, LONDON, W.1

MAY NOTICES 1947

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

OFFICE HOURS

The offices of the Society are now open from 9 a.m. to 5 p.m., Monday to Friday, and closed on Saturday *except* for the Library, which is open from 9.30 to 12.30 p.m.

VACANCIES ON CLERICAL STAFF OF THE SOCIETY

Owing to the increase of membership of the Society and increase of activities there are several vacancies for clerical staff. The Secretary would be glad to hear from any members who know of girls to fill the following positions:—

General Office

Shorthand typist for membership enquiries, general correspondence. Some experience necessary.

Membership Department

Junior shorthand typist for work dealing mainly with applications, elections and records of members. Previous office experience not necessary.

Accounts Department

Junior with knowledge of typing. Previous office experience not necessary.

Records Department

Junior typist to keep records of members' addresses, etc., including cutting stencils. Previous office experience not necessary.

The office hours are 9 a.m. to 5 p.m., Monday to Friday. The Society has one of the finest offices in London, so making the conditions of work more pleasant than is generally the case.

CONTENTS OF THE MAY JOURNAL

The War in the Ether by Air Vice-Marshal E. B. Addison, C.B., C.B.E.

Annual Report of Council for 1946.

Performance Calculation for Jet-Propelled Aircraft by R. K. Page, B.Sc.(Eng.), A.F.R.Ae.S.

Design for Maintenance—Correspondence.

AERONAUTICAL CONFERENCE

Arrangements are now being made to hold an Aeronautical Conference in the first week of September next. The Conference, which is being arranged by the Society, will last four

days and papers will be read by leading American and British authorities on their special subjects.

In connection with the Conference the Institute of the Aeronautical Sciences is working in close co-operation with the Society and has already informed the Society that many of the leading American designers will be attending.

It is probable that the meeting will take place in London, but all arrangements are tentative at present, and this must be taken as a preliminary notice only to members and others, so that they may make arrangements to keep the first week in September clear.

The week following will be that of the S.B.A.C. Flying Display and Static Exhibition and will be followed by the Society's Garden Party on Sunday, 14th September, 1947.

Fuller particulars of both the Conference and the Garden Party will be published in the June Journal.

LIST OF MEMBERS

A List of Members of the Society is being prepared. Members should already have received a special post card on which they are asked to fill in their name, grade of membership of the Society, rank or title (if any), any letters to which they are entitled (*e.g.*, F.R.S., M.I.Mech.E., etc.) and address, as they wish them to appear in the List.

The Secretary will be glad if members will return the cards, filled in, as soon as possible please.

ANNUAL GENERAL MEETING

The Annual General Meeting of the Society was held at 4 Hamilton Place, W.1, on the 28th March, 1947, at which the Annual Report and Balance Sheet of Aerial Science Ltd. and Aeronautical Trusts Ltd. for 1946 was approved.

Brief extracts of the main points in the report are given below for the information of members not receiving the Journal.

Total membership of the Society at 31st December, 1946—6,434.

Excess of income over expenditure for 1946—£1,307 7s. 4d.

ELECTION OF COUNCIL MEMBERS FOR 1947-49

As a result of the ballot declared at the Annual General Meeting the following were elected to Council for 1947-49:—

Professor L. Aitchison, D.Met., B.Sc., F.R.I.C., M.I.A.E., F.R.Ae.S.
Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S.
S. Camm, C.B.E., F.R.Ae.S.
W. S. Farren, C.B., M.B.E., M.A., F.R.S., M.I.Mech.E., F.R.Ae.S.
Professor A. A. Hall, M.A., F.R.Ae.S.
Dr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.I.Ae.S., F.R.Ae.S.
S. Scott Hall, A.C.G.I., M.Sc., D.I.C., F.R.Ae.S.
P. G. Masefield, M.A., F.R.Ae.S.
Captain C. F. Uwins, A.F.C., O.B.E., F.R.Ae.S.
Dr. H. C. Watts, M.B.E., D.Sc., M.Inst.C.E., F.R.Ae.S.

The Council for the year 1947-1948 is therefore:—

President—Sir Frederick Handley Page, C.B.E., F.R.Ae.S.

Past Presidents—Sir A. H. Roy Fedden, M.B.E., D.Sc., M.I.Mech.E., M.I.A.E., M.S.A.E., F.R.Ae.S.

Mr. A. Gouge, B.Sc., F.R.Ae.S.

Mr. Griffith Brewer, Hon.F.R.Ae.S.

Vice-Presidents—Dr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.I.Ae.S., F.R.Ae.S.

Sir Oliver Simmonds, M.A., F.R.Ae.S.

Mr. N. E. Rowe, C.B.E., B.Sc., D.I.C., F.R.Ae.S.

Council Members

Professor L. Aitchison, D.Met., B.Sc., F.R.I.C., M.I.A.E., F.R.Ae.S.

Mr. E. J. N. Archbold, B.Sc., Grad. R.Ae.S.

Air Commodore F. R. Banks, C.B., O. B. E., M. I. A. E., F. I. P., M.S.A.E., M.I.Mech.E., F.R.Ae.S.

Lord Brabazon of Tara, M.C., F.R.Ae.S.

Sir John S. Buchanan, C.B.E., A.M.I.Mech.E., F.R.Ae.S.

Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S.

Mr. S. Camm, C.B.E., F.R.Ae.S.

Mr. G. P. Douglas, O.B.E., M.C., D.Sc., F.R.Ae.S.

Mr. A. G. Elliott, C.B.E., M.I.A.E., M.S.A.E., F.R.Ae.S.

Mr. W. S. Farren, C.B., M.B.E., M. A., F. R. S., M. I. Mech. E., F.R.Ae.S.

Professor A. A. Hall, M.A., F.R.Ae.S.

Mr. S. Scott Hall, A.C.G.I., M.Sc., D.I.C., F.R.Ae.S.

Mr. E. T. Jones, O.B.E., M.Eng., F.R.Ae.S.

Sir Ben Lockspeiser, M.A., F.C.S., F.R.Ae.S.

Mr. P. G. Masefield, M.A., F.R.Ae.S.

Mr. W. G. A. Perring, F.R.Ae.S.

Captain C. F. Uwins, A.F.C., O.B.E., F.R.Ae.S.

Dr. H. C. Watts, M.B.E., D.Sc., M.Inst.C.E., F.R.Ae.S.

Honorary Librarian—Mr. J. E. Hodgson, Hon.F.R.Ae.S.

Honorary Treasurer—Captain C. F. Uwins, A.F.C., O.B.E., F.R.Ae.S.

Solicitor—Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S.

Secretary—Captain J. Laurence Pritchard, F.I.Ae.S., Hon.F.R.Ae.S.

NOTE.—The President and Vice-Presidents are elected in May or June and take office in October of each year.

GRADUATES' AND STUDENTS' SECTION

The following committee were elected at the Section's Annual General Meeting on 19th March, 1947:—

Chairman—Mr. R. J. Ross, Student.

Vice-Chairman—Mr. R. L. E. Toms, Graduate.

Committee—Mr. G. Jackson, Graduate; Mr. J. W. F. Housego, Graduate; Mr. K. R. Obee, Graduate; Mr. C. S. Cranwell, Graduate; Mr. J. C. Wallin, Graduate; Mr. F. H. Bond, Student; Mr. P. F. N. Edwards, Student.

Ex-officio Member—Mr. E. J. N. Archbold, Graduate.

Hon. Secretary—Mr. J. G. Roxburgh, Graduate, 62 Fitzjohns Avenue, London, N.W.3.

Assistant Hon. Secretary—Mr. M. C. Campion, Graduate, 6a Mildenhall Road, Clapton, London, E.5.

Members of the Section are invited to write to the Honorary Secretary about any matters connected with the Society or the Section which they wish to raise.

WILBUR WRIGHT MEMORIAL LECTURE

The thirty-fifth Wilbur Wright Memorial Lecture will be read at 6 p.m. on Thursday 29th May 1947, by Mr. John K. Northrop, on The Development of All-Wing Aircraft.

The Lecture will be held at the Institution of Civil Engineers, Great George Street, Westminster, S.W.1. Tea will be served before the meeting. Visitors will only be admitted by ticket, obtainable through members. Because of the severe shortage of paper advance copies of the lecture will not be available.

THE INSTITUTION OF MECHANICAL ENGINEERS—CENTENARY

The Council of the Institution of Mechanical Engineers have extended a special invitation to members of the Royal Aeronautical Society to a meeting on Aircraft Power Plants which will be held on Tuesday 10th June 1947, as part of the Centenary celebrations of the Institution.

The meeting will begin at 10.30 a.m. and the following short lectures will be given:—

Aeroplane Power Plant, Reciprocating, by Dr. H. R. Ricardo (Past President) M.I.Mech.E., F.R.S., F.R.Ae.S.

Aeroplane Power Plant, Internal Combustion Turbine, by Mr. Hayne Constant, M.A., M.I.Mech.E.

Aeroplane Power Plant in U.S.A., by Professor W. J. King, Cornell University, New York, with Dr. Hawthorne, Massachusetts Institute of Technology, as co-author.

Members who wish to attend the meeting should apply to The Secretary, Royal Aeronautical Society. A limited number of tickets only will be available.

BLACKPOOL FLYING DISPLAY

From 2nd July to 23rd July 1947, the Air League of the British Empire will be holding an Exhibition and Flying Display at the airport at Squire's Gate, Blackpool.

The Exhibition will include all types of modern British aircraft and there will be special flying displays on 2nd, 9th and 16th July.

The Air League have kindly offered to arrange a special enclosure for the flying displays if a sufficient number of members of the Society wish to attend.

The price of tickets is 10/- and applications should be made, stating that you are a member of the Society, to the Air League of the British Empire, Kinnaird House, 1 Pall Mall East, London, S.W.1, by 16th June 1947, at the latest.

NORTHERN HEIGHTS MODEL FLYING CLUB

Northern Heights Model Flying Club will hold a gala day at Langley Aerodrome, Slough, on Sunday, 20th July, 1947, again through the courtesy of the Directors of Hawker Aircraft Ltd. There will be a display of full-size aircraft as well as competitions for every type of model aircraft. The competitions will begin at 11 a.m.

The club extends a warm invitation to any members of the Society who are interested. Members will be admitted free on showing their membership cards.

BRANCH LECTURES AND NOTICES

LUTON BRANCH

7th May, 1947—Pneumatics for Aircraft, by Group Captain C. S. Morice.

4th June, 1947—Fuels and Oils for Aircraft Turbines, by Dr. C. G. Williams, Ph.D., M.I.Mech.E., F.Inst.Pet., A.F.R.Ae.S.

Meetings are generally held at the George Hotel, Luton, at 7 p.m.

READING AND DISTRICT BRANCH

7th May, 1947—Propeller Turbine Installations, by Mr. A. C. Clinton, F.R.Ae.S., of the Bristol Aeroplane Co. Ltd.

28th May, 1947—FREE FOR ALL. At this meeting any member of the Branch may speak for about 10 minutes on any aeronautical subject. Please let the secretary know beforehand of your intention to speak.

All Lectures are held at 6 p.m. in the Monthly Staff Dining Room, Miles Aircraft Ltd.; tea will be served from 5.30 p.m.

GRADUATES' AND STUDENTS' SECTION

Tuesday, 10th June, 1947—Radio Aids to Airline Operation, by F. R. Willis.

Meetings are held at 7.30 p.m. in the Library of the Society, 4 Hamilton Place, W.1.

JOURNAL BINDING

Because of increased costs, the prices of binding of Journals will be as follows:—

1946 Volume 12/6.
Previous Volumes 13/6.

Journals should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the office of the Society.

CHANGES OF ADDRESS

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address.

When notifying changes please give the following particulars:—

Name (in block letters).
Grade of membership.
New address (in block letters).
Old address.

Changes of address must be received **before the 15th of the month** in order to be effective for the Journal for the following month.

ELECTION OF MEMBERS

The following new members have been elected:—

Fellows (*from Associate Fellows*)

George Henry Abell, Harry Bateman, William Gee Bickley, Selig Brodetsky, William Charles Clothier, William Ernest Cooper, Stuart Duncan Davies, Frederick John Wingfield Digby, Sydney George Ebel, George William Hoggan Gardner, Jack Hanson, Frank Holroyd, John Samuel Irving, Godfrey Henry Lee, Maurice Luby, Neil Shaw Muir, William

Douglas Murray, Cyril George Pullin, Thomas Rowntree, Herbert Sammons, Glynn Silyn Roberts, George Thomas Smith-Clarke, William Lyall Taylor, Walter Tye, Hugh Frederick Vessey, Leonard William Warner, George Ernest Watt, Charles Garrett Williams, Joseph Wright.

Associate Fellows

Alexander Duncan Baxter, Tadeusz Berezowski, Cyril Francis Caunter, Harry Davis, William Tait Dow (from Graduate), Robert Roger Duddy, Ernest Finn (ex-Student), George Gilbert Gale (from Graduate), Charles Clarence Greensmith (from Associate), Ronald Leslie Edmund Henson (from Student), Peter Jessop, Harold Kember, Jack Kirby (from Associate), Barry Pemberton Laight (from Graduate), William Thomas Owen Lewis, Hector Maurice McLachlan, Ralph Lionel Maltby (from Student), Richard James Packman (from Student), Eric Bell Pearson, John Norman Justice Rowley, Duncan John Stewart (ex-Student), Arthur Edward Swain, Alan William Thorpe, Alan Wilson.

Associates

Edwin Bade, Frederick George Banting, Leonard William Barrett, William Barton, Alfred Charles William Booth, Johannes Gerhardus Borman, Ernest James Brunckhurst, Roderick William Burn-Callander (from Companion), Charles William Clark, George Gilmour Clark (from Student), Patrick Lawrence Crowell, William Gerald Fitz-Gibbon, Gordon Henry Harrington, Allison William Beckett Hester, Thomas Charles Hugill, George Henry Jones, Meyer Julian Isador Kemper (from Student), Philip George Kendrick, Frederick Charles Kirkpatrick, Edward Miller Langford, George Andrew Lewis, Raphael A. Marcus, Peter Morrell, Leon James Pearce, William Thomas Pether, Arthur Higginson Phillips, John Gilbert Russell (from Student), Stanley Rymell, Vivian Egerton Saunders (from Student), William James Sellen, Jerzy Sieluzycki, James Purkis Smith, Maurice Francis Summers, Stanley Tipper, Brian Reginald Walker, William Harold Wardall.

Graduates

Ronald Claude Graham Boxer (from Student), Edward Bulger, Richard Peter Castle (from Student), John Charles Digby Cotes (from Student), William Ewing (from Student), John Richard Carter Fearon (from Student), Douglas Frederick Handel, Richard George Harvey (from Student), John Bertram Holliday, Peter Robert Keeble (from Student), Murdoch Alexander Mackenzie, Frank Keith Main, James Gordon Mason (from Student), James Meadows (from Student), Joseph Merrick (from Student), Oliver Reginald Barton Moorman (from Student), Robert James Newton, Michael John Rant (from Student), Hans Ritter (from Student), Frederick Alan Spurr, Stuart Summersbee, Henry Lambert Garbutt Sunley (from Student), Rupert Whitfield Traill-Nash, Norman Sydney Turl, Richard Willis, Herbert Wager Winterbottom, John Leonard Wood (from Student).

Students

Michael Austin, Thomas Edgar Brown, Peter George Bullen, Dennis Gordon James Caddy, John Bradley Chaplin, John Charles Cooper, Peter Davenport, David Wilfred Holland Godfrey, John Edward Grieves, John Martin Hare, James Rentoul Henry, David Arundel O'Clarey, Robert George Onions, Geoffrey Keith Charles Pardoe, David Parsons, John Edward Barrance Perkins, Peter Webster Rendell, John Kerlin Scott, John Kenneth Whitwell.

Companions

Louis S. Armandias, Denis Follows, Albert Frenkel, David Henry Gason Ince, Md. Rahat Ali Rizvi.

ACKNOWLEDGMENTS

The Council acknowledge with grateful thanks the gift of models of the Hotspur MK.II-Training Glider (1/48th Scale) and the Hamilcar MK.X (Power Assisted) Glider (1/48th Scale) from General Aircraft Limited; photographs of British aircraft used in the 1914-18 War from Captain G. U. Allan, Associate Fellow; a copy of " Modern Handbook of Aeronautics 1919 " by A. Judge, from E. V. Dolby, Esq., Companion.

They also acknowledge gratefully from Mr. G. Tilghman Richards, Memoranda re Annular Type aeroplanes as developed by the C.L. Co. under the direction of G. T. Richards 1910-14. The memoranda consists of patents, photographs and calculations of the well-known Cedric Lee annular gliders and aircraft, which are of considerable historical interest.

ADDITIONS TO THE LIBRARY

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

A.a.331.—Aerodynamics. N. A. V. Piercy. English Universities Press. 1947.

B.g.152.—Aircraft of the United States. Volume II. R. A. Savile-Sneath. Penguin Books. 1946.

BB.b.122.—Theory of Structures. Timoshenko and Young. McGraw Hill. 1945.

E.b.117.—Proceedings of the Society for Experimental Stress Analysis. C. Lipson (Editor). Addison Wesley Press, New York. 1946.

E.c.30.—An Escalator Method in Engineering Vibration Problems. Joseph Morris. Chapman & Hall. 1947.

F.b.43.—Standard Methods for Testing Petroleum and its Products. 8th Edition. Institute of Petroleum. 1947.

L.d.116.—*Notices to Airmen*. Nos. 65, 66, 67, 68, 69, 70, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82.

N.d.1.—Atomic Energy in Cosmic and Human Life. George Gamow. Cambridge University Press. 1947.

S.e.137.—Middle East, 1940-42. Philip Guedella. Hodder & Stoughton. 1944.

X.a.57.—Handbook of Modern Aeronautics. A. W. Judge. The Library Press, London. 1919.

X.c.156.—Russian-English Technical and Chemical Dictionary. L. I. Callaham. John Wiley. 1947.

X.e.60.—American Aviation Directory. Volume 7. Number II. Wayne W. Parrish. American Aviation Publications. 1946.

A.R.C. Reports and Memoranda

1838.—*The calculation of the profile drag of aerofoils. H. B. Squire and A. D. Young.*

1891.—*Physical properties of the standard atmosphere. R. C. Pankhurst and J. F. C. Conn.*

1929.—*Two-dimensional supersonic aerofoil theory. M. J. Lighthill.*

2001.—*The supersonic theory of wings of finite span. M. J. Lighthill.*

2004.—*Theoretical forces and moments on a thin aerofoil with hinged flap at supersonic speeds. A. R. Collar.*

2096.—*Theoretical lift force, pitching and hinge moments of an aerofoil with a cambered flap. J. Ripley.*

The following reports have also been received:—

British Intelligence Objectives Sub-Committee

B.I.O.S. Final Reports No. 771, Item Nos. 4, 5, 9, 18, 19, 25, 26, 27, 28, 29, 30 and 31.
No. 1203, Item Nos. 7 and 21.
No. 1207, Item No. 22.

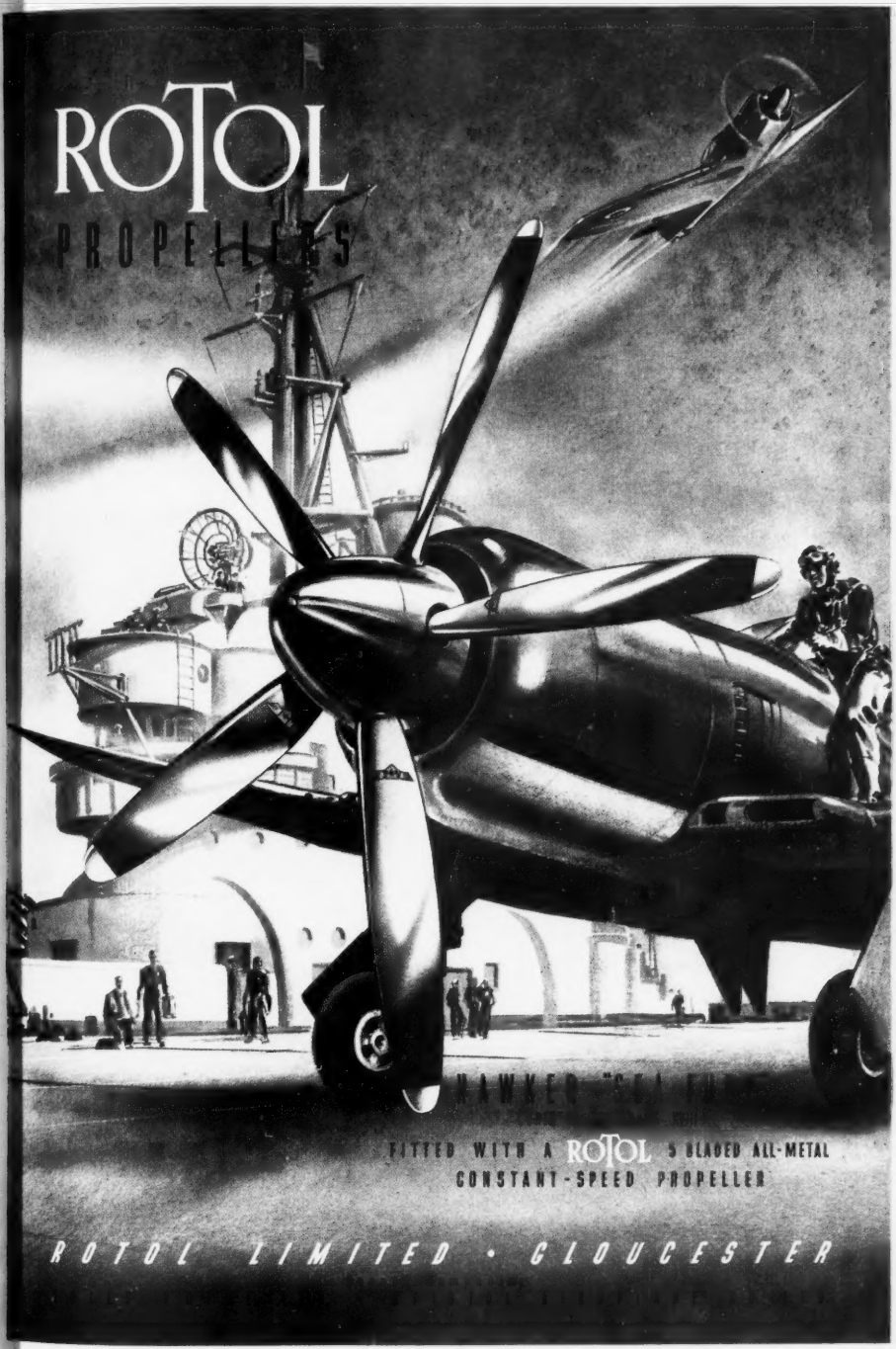
F.I.A.T. Final Report Nos. 620 and 924.

R. Politecnico di Torino. Laboratorio di Aeronautica

Sul calculo delle struttore a cassone. P. Cicala.

J. LAURENCE PRITCHARD,
Secretary.

Made and Printed in Great Britain by the Lewes Press, Lewes. Sussex

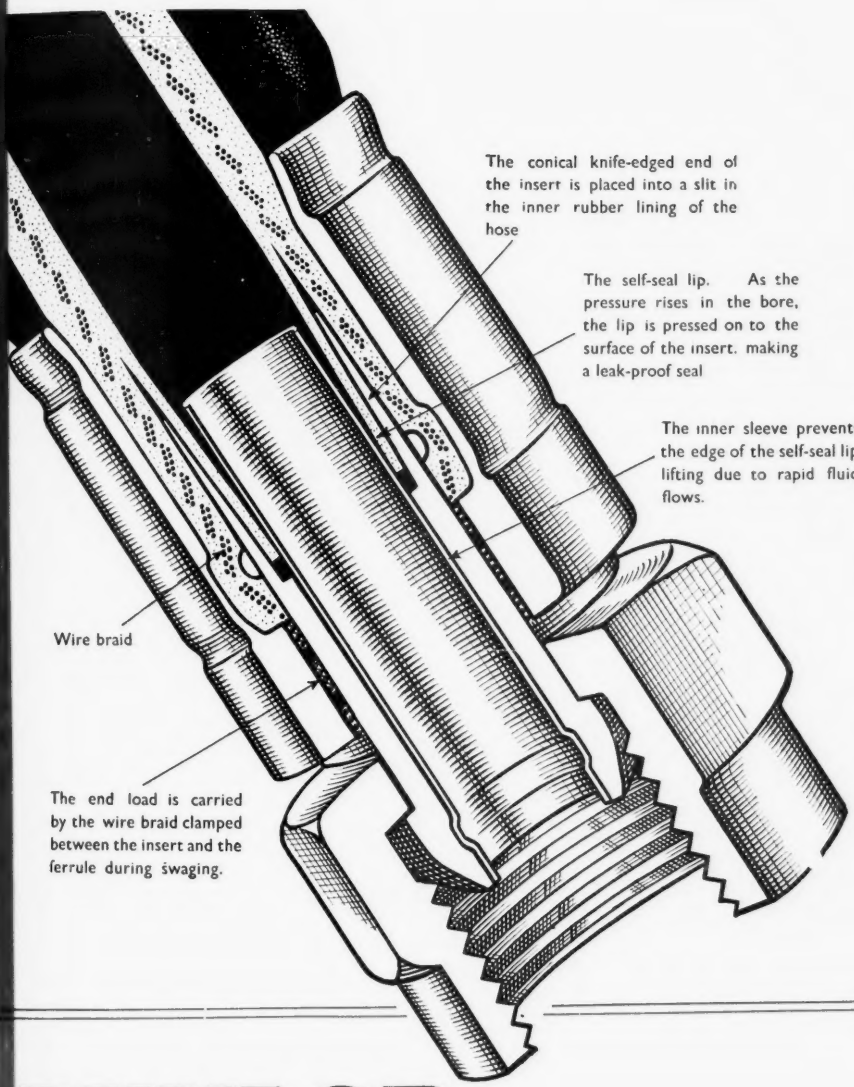

ROTOL
PROPELLERS
HAWKER
FITTED WITH A ROTOL 5 BLADED ALL-METAL
CONSTANT-SPEED PROPELLER
ROTOL LIMITED · GLOUCESTER

Exact information, responsible commentaries and topical illustrations are among the features which have given these four representative Temple Press Publications positions of authority in the world of aviation.

TEMPLE PRESS LIMITED

BOWLING GREEN LANE, LONDON, E.C.1. TERMINUS 3636

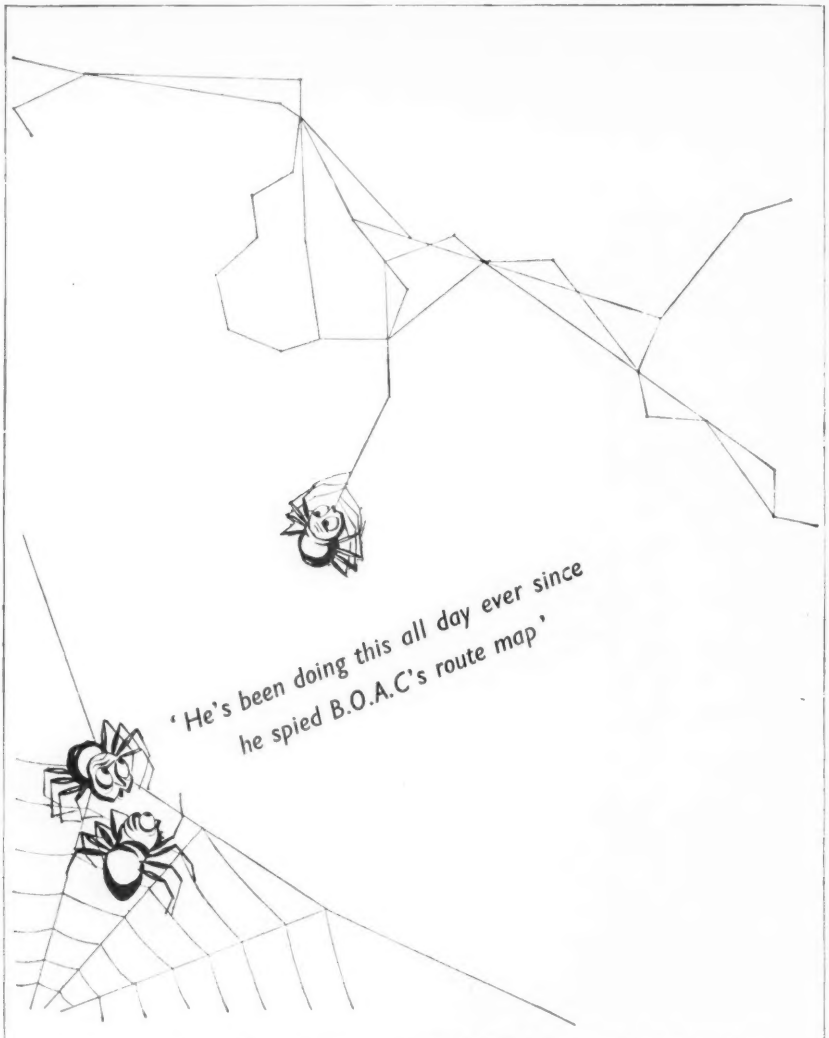
TEMPLE PRESS


The conical knife-edged end of the insert is placed into a slit in the inner rubber lining of the hose
The self-seal lip. As the pressure rises in the bore, the lip is pressed on to the surface of the insert, making a leak-proof seal
The inner sleeve prevents the edge of the self-seal lip lifting due to rapid fluid flows.
Wire braid
The end load is carried by the wire braid clamped between the insert and the ferrule during swaging.

DUNLOP

HIGH PRESSURE HOSE ASSEMBLY

DUNLOP RUBBER Co. Ltd., *Aviation Division*, COVENTRY



As web spinners, we may be weak on symmetry; but the B.O.A.C. network does get you places. In it there are over 72,000 miles of Speedbird routes linking Britain · Canada · U.S.A. Middle East · South, East and West Africa · India · Far East · Australia and New Zealand.

B·O·A·C SPEEDBIRD ROUTES ACROSS THE WORLD

BRITISH OVERSEAS AIRWAYS CORPORATION IN ASSOCIATION WITH Q.E.A., S.A.A., T.E.A.

More power to the engines

LODGE

PLUGS

WITH THE *PINK* SINTOX INSULATION

Lodge Plugs Ltd., Rugby

WORLD WIDE AUTHORITIES

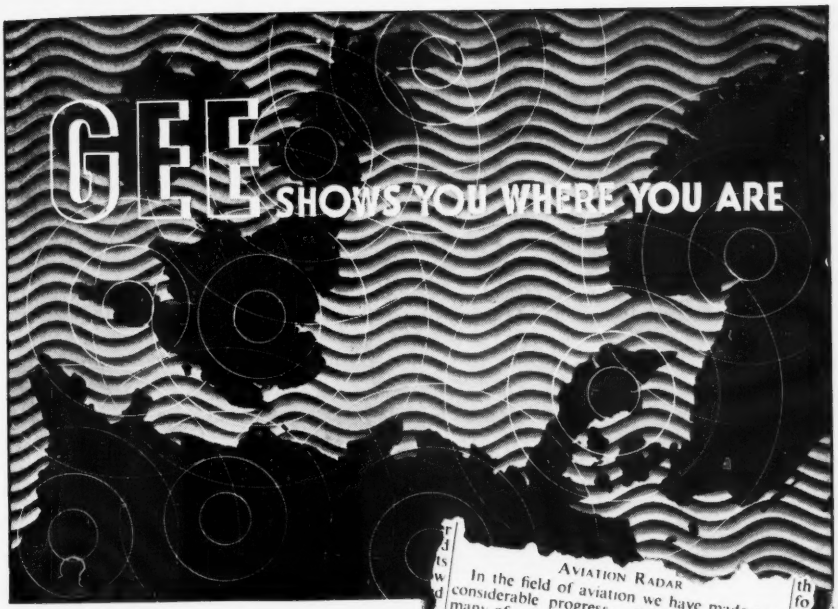
COVERING EVERY PHASE OF DESIGN, OPERATION AND PRODUCTION OF ALL TYPES OF AIRCRAFT

FLIGHT (weekly) provides the most authentic information on world aeronautical affairs. It covers every aspect of development and progress in aircraft and power unit design and operation. AIRCRAFT PRODUCTION (monthly) is the journal of the aircraft manufacturing industry, specialising in tools and works production processes. Both journals serve the interests of all concerned with the future progress of British aviation. Technical information is supplemented by brilliant functional drawings. Circulation is world wide. Annual subscriptions (Home and Overseas): FLIGHT, £3 1s. 0d.; AIRCRAFT PRODUCTION, £1 14s. 6d.

Published in conjunction with these journals, FLIGHT HANDBOOK (212 pages, 7s. 6d. net) is essentially a manual for the student, whilst GAS TURBINES AND JET PROPULSION (272 pages, 12s. 6d. net) by G. Geoffrey Smith, has been widely adopted as the standard text on the subject.

ASSOCIATED ILIFFE PUBLICATIONS

DORSET HOUSE, STAMFORD STREET, LONDON, S.E.1. WATERLOO 3333 (50 LINES)



GEE

The Pulse System of Hyperbolic Navigation

DAY AND NIGHT RANGE of 300 miles at 5,000 feet and 150 miles at 2,100 feet.

ACCURACY of 100 yards or ½% of Range whichever is the greater.

OPERATION TIME of 10 seconds per fix.

IMMEDIATELY operative within service range of any chain of GEE ground stations.

UNAFFECTED by static interference.

CONTINUITY unaffected by service interruptions.

NOT SUSCEPTIBLE to jamming.

NO AMBIGUITIES.

AVIATION RADAR

In the field of aviation we have made very considerable progress. "GEE," famous to many of you, briefly is a pulse system of navigation developed early in the war in collaboration with H.M. Government's Telecommunications Research Establishment. It was "GEE" that made the thousand-bomber raids on Germany possible. It was fully developed and manufactured exclusively by us for almost two years during the war.

Networks of "GEE" stations already exist, covering most of the United Kingdom and a large part of Europe, and our Government have recently announced their intention of making available to those liberated countries requiring it complete ground installations, as well as a limited number of airborne installations from surplus stocks, thus providing them with temporary navigation facilities. The British European Airways, after thoroughly examining all competitive navigational aids, recently announced their decision to adopt "GEE". They are planning its introduction into all of their aircraft, in order that their equipment may be brought up to the only known proven system readily available for safe modern operation.

Extract from an address made by Mr. T. A. Macauley, Chairman of A. C. Cossor Ltd., on 14th August, 1946, at the company's 8th General Meeting.

GEE airborne and ground equipment developed, engineered and FIRST PRODUCED by

COSSOR

FIRST IN THE WORLD WITH RADAR RECEIVERS

PRECISION CASTING

An American Authority recently stated:

'Precision investment casting is a comparatively undeveloped industrial art, but it has reached the stage where it is reducing costs and improving qualities on tens of thousands of products. It is capable of accuracies roughly approximate to those of grinding. It can handle practically any metal that can be cast at all. The process makes its most valuable contributions by producing intricacies in parts, and by handling with ease metals that are difficult or even impossible to fabricate economically by other methods.'

MATERIALS AND METHODS, *March 1946*

If that extract interests you, we welcome an opportunity to supply some details of the part played by Ethyl Silicate in precision casting

ALBRIGHT & WILSON

ETHYL SILICATE

Albright & Wilson Ltd., 49 Park Lane, W.1 *Tel: Gro 1311*

TBW 8/[illegible]

Micron-size menace...

The internal combustion engine is dangerously vulnerable to the abrasive action of air-borne dust. Intensely hard silica particles enter via curburettor and crankcase breather—they mix with the lubricating oil . . . and play havoc with bearings and cylinders. *And the most dangerous particles are those between one and five microns in size* . . . between one hundredth and one twentieth the diameter of a human hair . . . small enough to pass crude methods of filtration—large enough to span the oil film Remember the micron-size menace in any consideration of engine filtration . . . remember too that if VOKES had not conquered this menace, our desert tank victories would not have been possible—our aircraft would have been grounded for overhaul after a few hours' flying in many theatres of war. Where a VOKES filter is recommended for a purpose its efficiency rating can be relied upon as an *absolute* figure . . . and where *special* conditions must be overcome, VOKES engineers will gladly give it *special* consideration.

VOKES
Pioneers of scientific filtration

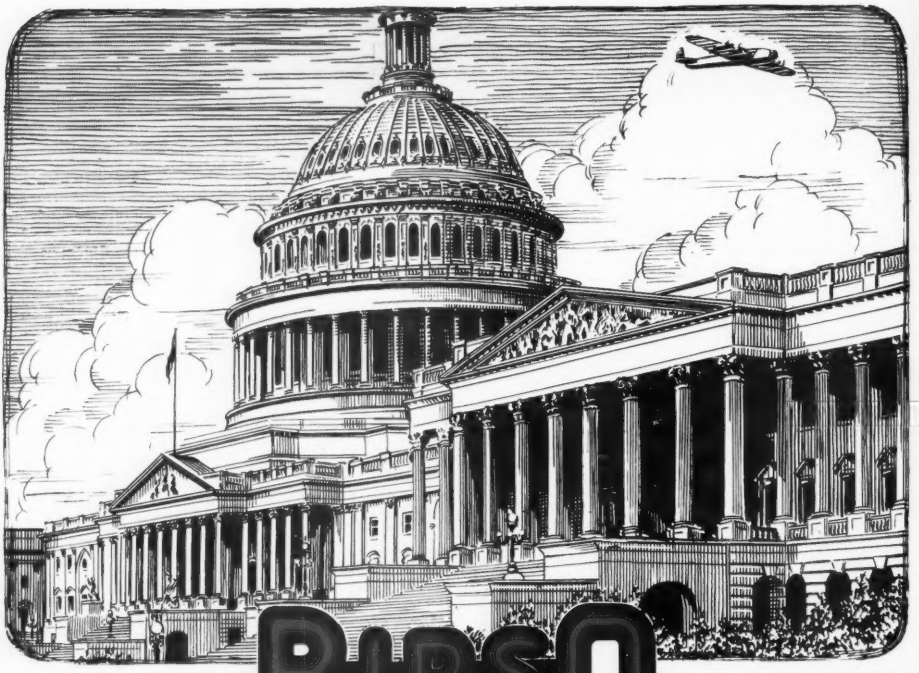
VOKES LTD., GUILDFORD, SURREY
also at Paris, Brussels, New York, Sydney, Toronto, Johannesburg, Bombay

VOKES CONTRIBUTIONS TO MODERN AVIATION

Today VOKES filters are standard equipment in numerous aircraft applications...on engine air-intake, fuel and oil . . . on hydraulic systems . . . on test beds. New developments are placing even more emphasis on scientific filtration. Units to silence and filter the air on both sides of "blowers" used for cabin pressurisation . . . fuel filters of the highest efficiency for gas turbines . . . high pressure filters for 'jet' bearing lubrication . . . these are only a few of the developments in which VOKES leadership is being maintained.

AMBER CROSS

SYMBOL OF PROTECTION FOR MAN AND MACHINE



The Capitol *Washington*

BIRSO
TRADE MARK

NON-FERROUS
CASTINGS and
MACHINED PARTS
for Civil and Fighter Aircraft

'Birso' Chill Cast Rods and Tubes,
Ingot Metals, etc.

FULLY APPROVED BY ADMIRALTY AND A.I.D.

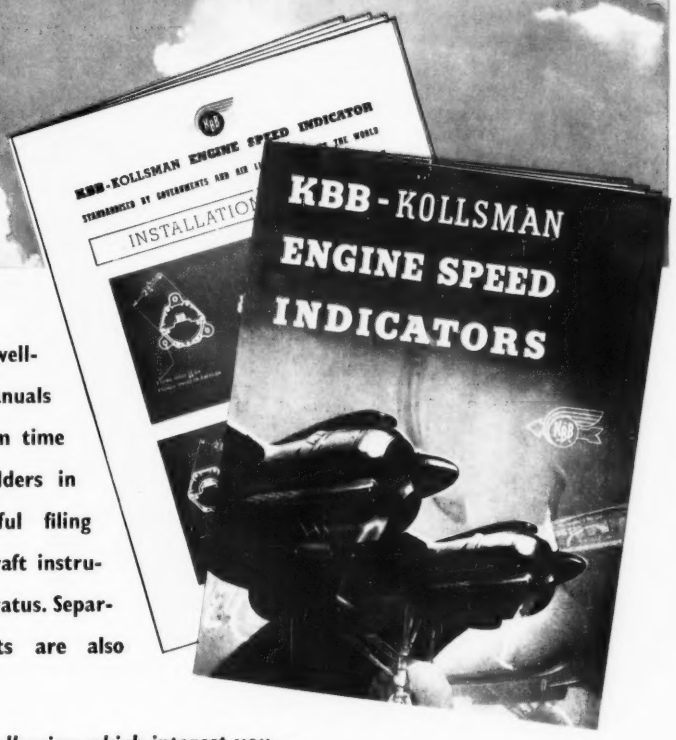
B71

T. M. BIRKETT & SONS, LTD.
HANLEY · STAFFS.

Grams Birkett, Hanley 'Phone Stoke-on-Trent 2184-5-6

Have you had this series of

AIRCRAFT INSTRUMENT FOLDERS?



In addition to our well-known Maintenance Manuals we have published from time to time descriptive folders in colour containing useful filing material on Kelvin aircraft instruments and testing apparatus. Separate installation leaflets are also available.

Write for any of the following which interest you —

K.B.B.-KOLLSMAN SIMPLE ALTIMETERS, K.B.B.-KOLLSMAN SENSITIVE ALTIMETERS, K.B.B.-KOLLSMAN RATE OF CLIMB INDICATORS, K.B.B. AIRSPEED INDICATORS, K.B.B.-KOLLSMAN ENGINE SPEED INDICATORS, KELVIN SENSITIVE AIR PRESSURE GAUGE, KELVIN AIRCRAFT INSTRUMENT TESTING APPARATUS, K.B.B.-VIBROGRAPH, KELVIN SENSITIVE AIRCRAFT BAROMETER.

K.B.B.

KELVIN AIRCRAFT INSTRUMENTS

proven in reliability—ahead in design

KELVIN BOTTOMLEY AND BAIRD LIMITED · BASINGSTOKE

In Empire Air Development

FIRST Aerial Service in Eastern Australia . . . . . Charleville to Cloncurry. Hence 'Queensland and Northern Territory Aerial Services' Q.A.N.T.A.S. **1922**

FIRST Aircraft to be manufactured in Australia under licence from overseas . . . a DH50A, built by Qantas at Longreach **1926**

FIRST Flying Doctor service established in Australia by Qantas at Cloncurry **1928**

FIRST Official experimental Airmail between Australia and Britain, in association with Imperial Airways **1931**

FIRST Four-engined Plane used in Australia . . . . . by Qantas on Brisbane-Singapore service (a DH86). **1935**

FIRST Through Flying Boat service to Singapore by Qantas, and — in association with Imperial Airways — to London . . **1938**

FIRST Regular Crossing of the Indian Ocean . . . the world's longest air hop . . . by Qantas in association with B.O.A.C. with Catalinas **1943**

FIRST With B.O.A.C. and Tasman Empire Airways, to re-establish the British Air Route . . . to help maintain British Empire Air supremacy in the revolutionary developments in the Age of Flight **1946**

AUSTRALIA'S INTERNATIONAL AIRLINE

Qantas Empire Airways

in association with

BRITISH OVERSEAS AIRWAYS CORPORATION B·O·A·C

PITMAN BOOKS
for Aero Engineers

METALLURGY *for Aircraft Engineers, Inspectors and Engineering Students*

By R. A. Beaumont, A.F.R.Ae.S. The author's wide experience in the training of aero engineers is used with effect in this book which deals chiefly with steels and light alloys employed in aircraft construction. His treatment of the subject is clear and exhaustive, and will prove of considerable interest and value to progressive aeronautical engineers and students. **25s.** net.

AIRCRAFT ENGINES OF THE WORLD 1946

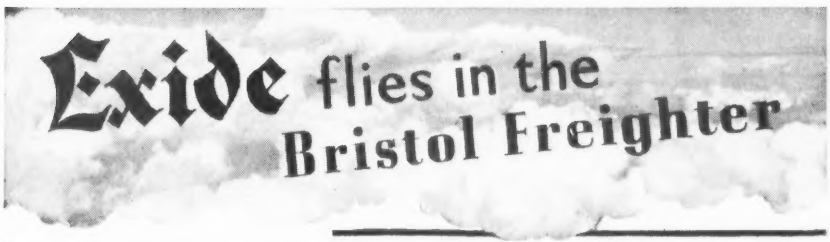
By Paul H. Wilkinson. Contains specifications and photographs of the latest reciprocating and jet propulsion engines, many of them hitherto restricted—the finest collection of aeronautical data ever published. **45s.** net.

GEARS

By H. E. Merritt, D.Sc., M.I.Mech.E., M.I.A.E. Deals clearly and thoroughly with gear tooth geometry, efficiency, lubrication and load carrying capacity of gear drives, and presents new and simplified treatments of epicyclic trains and change gear calculations. About 300 diagrams and photographs. Second edition. **30s.** net.

Pitman House - Parker Street - Kingsway - London - W.C.2.

PITMAN



THE BRISTOL FREIGHTER, foremost cargo-carrying aircraft, uses Exide exclusively. So, too, does another versatile Bristol aircraft, the Wayfarer. In their latest passenger and freight-carrying aircraft, the vast majority of Britain's leading aircraft manufacturers are today fitting Exide as initial equipment. The reason? Lighter weight with greater capacity—better performance with longer life.

The following aircraft are fitted with EXIDE *Batteries as initial equipment:*

AIRSPEED AMBASSADOR	MILES AEROVAN
AIRSPEED CONSUL	MILES GEMINI
AVRO TUDOR I	MILES MARATHON
AVRO TUDOR II	MILES MESSENGER
BRISTOL FREIGHTER	PERCIVAL PRINCE
BRISTOL WAYFARER	PERCIVAL PROCTOR
CUNLIFFE-OWEN CONCORDIA	SHORT SANDRINGHAM 'V'
HANDLEY PAGE HALTON	SHORT SOLENT
HANDLEY PAGE HERMES	SHORT SEALAND
VICKERS VIKING	

A12n

THE CHLORIDE ELECTRICAL STORAGE COMPANY LIMITED, EXIDE WORKS, CLIFTON JUNCTION, NR. MANCHESTER

TRAFFIC EFFICIENCY IN THE VICKERS VIKING. An aircraft planned for a particular job . . . and planned down to the smallest detail to do that job with maximum operating efficiency. Large entrance door and wide gangways . . . vestibule for coat hangers and light luggage . . . low loading to large luggage hold . . . pantry completely equipped for substantial meals service. Points that make for easy passenger handling . . . points appreciated, for example, by British European Airways, whose scheduled services have been safely and regularly maintained by Vickers Viking medium airliners, current product of Vickers-Armstrongs long experience in aircraft design and construction.

VICKERS-ARMSTRONGS LIMITED · AIRCRAFT SECTION, WEYBRIDGE WORKS, WEYBRIDGE, ENGLAND

THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY

With which is incorporated The Institution of Aeronautical Engineers

CONTENTS *MAY 1947*

THE WAR IN THE ETHER
By Air Vice-Marshal E. B. Addison, C.B., C.B.E. 425—439

PERFORMANCE CALCULATION FOR JET-PROPELLED AIRCRAFT
By R. K. Page, B Sc. (Eng.), A.F.R.Ae.S. :: 440—450

EIGHTY-SECOND ANNUAL REPORT OF THE COUNCIL 1946-47 :: :: :: :: 451—470

CORRESPONDENCE :: :: :: :: 471—480

The Journal is published monthly at the Offices of the Society, 4 Hamilton Place, Piccadilly, London, W1. None of the papers or paragraphs must be taken as expressing the opinion of the Council of The Royal Aeronautical Society unless such is definitely stated to be the case. Subscriptions per annum, £4 13 0 including postage; Single Numbers 7/6 or 7/9 post free. All communications for publication or Advertisements in the Journal, or on general matters affecting the Society should be addressed to—The Secretary, J. Laurence Pritchard, 4 Hamilton Place, W1. The Society's Bankers are Messrs. Coutts and Co.

Telephone: Grosvenor 3515 (5 lines) Telegraphic Address: Didaskolas, Audley, London.

The Council for the year 1947-1948 is as follows:—

PRESIDENT

SIR FREDERICK HANDLEY PAGE, C.B.E., F.R.Ae.S.

PAST PRESIDENTS

SIR A. H. ROY FEDDEN, M.B.E., D.Sc., M.I.Mech.E., M.I.A.E., M.S.A.E., F.R.Ae.S.

MR. A. GOUGE, B.Sc., F.R.Ae.S.

MR. GRIFFITH BREWER, Hon.F.R.Ae.S.

VICE-PRESIDENTS

DR. H. ROXBEE COX, Ph.D., D.I.C., B.Sc., F.I.Ae.S., F.R.Ae.S.

SIR OLIVER SIMMONDS, M.A., F.R.Ae.S.

MR. N. E. ROWE, C.B.E., B.Sc., D.I.C., F.R.Ae.S.

COUNCIL MEMBERS

Professor L. AITCHISON, D.Met., B.Sc., F.R.I.C., M.I.A.E., F.R.Ae.S.

Mr. E. J. N. ARCHBOLD, B.Sc., Grad.R.Ae.S.

Air Commodore F. R. BANKS, C.B., O.B.E., M.I.Aut.E., F.I.P., M.S.AE., M.I.Mech.E., F.R.AeS.

Lord BRABAZON OF TARA, M.C., F.R.Ae.S.

Sir JOHN S. BUCHANAN, C.B.E., A.M.I.Mech.E., F.R.Ae.S.

Major G. P. BULMAN, C.B.E., B.Sc., F.R.Ae.S.

Mr. S. CAMM, C.B.E., F.R.Ae.S.

Mr. G. P. DOUGLAS, O.B.E., M.C., D.Sc., F.R.Ae.S.

Mr. A. G. ELLIOTT, C.B.E., M.I.Aut.E., M.S.A.E., F.R.Ae.S.

Mr. W. S. FARREN, C.B., M.B.E., M.A., F.R.S., M.I.Mech.E., F.R.Ae.S.

Professor A. A. HALL, M.A., F.R.Ae.S.

Mr. S. SCOTT HALL, A.C.G.I., M.Sc., D.I.C., F.R.Ae.S.

Mr. E. T. JONES, O.B.E., M.Eng., F.R.Ae.S.

Sir BEN LOCKSPEISER, M.A., F.C.S., F.R.Ae.S.

Mr. P. G. MASEFIELD, M.A., F.R.Ae.S.

Mr. W. G. A. PERRING, F.R.Ae.S.

Captain C. F. UWINS, A.F.C., O.B.E., F.R.Ae.S.

Dr. H. C. WATTS, M.B.E., D.S.c., M.Inst.C.E., F.R.Ae.S.

Honorary Librarian: Mr. J. E. HODGSON, Hon.F.R.Ae.S.

Honorary Treasurer: Captain C. F. UWINS, A.F.C., O.B.E., F.R.Ae.S.

Solicitor: Mr. L. A. WINGFIELD, M.C., D.F.C., A.R.Ae.S.

Secretary: Captain J. LAURENCE PRITCHARD, F.I.Ae.S., Hon.F.R.Ae.S.

NOTE: The president and Vice-Presidents are elected in May or June and take office in October of each year.

THE ROYAL AERONAUTICAL SOCIETY

The 709th Lecture read before the Society on the 27th March 1947 at the Institution of Civil Engineers, Great George Street, London, W.1. In the chair, the President, Sir Frederick Handley Page, C.B.E., F.R.Ae.S.

THE WAR IN THE ETHER

by

Air Vice-Marshal E. B. ADDISON, C.B., C.B.E.

Air Vice-Marshal Addison served in the R.F.C during the first World War and from 1918-1921 *was at Cambridge University. After obtaining his degree, he was re-commissioned in the R.A.F. and served in India, Malaya, Palestine and Egypt. During this time he attended the Ecole Superieure d'Electricité in Paris, obtaining their diploma. In* 1940 *he commanded No.* 80 *Wing, and in* 1941 *he became Director of Signals and later of Telecommunications at the Air Ministry. From* 1943-1945 *he was A.O.C. No.* 100 *Group—the Group concerned primarily in the Radio War. He is now Air Officer Commanding No.* 90 *Group.*

1. INTRODUCTION.

A FEW MONTHS ago I was asked to deliver a lecture to the Royal United Services Institution on the Radio War. In the preamble to that lecture I explained that my treatment of the subject would not consist of a description of the various radio* devices which were used in the late war for purposes of communication, early warning and air navigation, but rather of a treatise on the methods that were employed to deny to our enemies the use of their radio services. My lecture dealt mainly, therefore, with the use of radio as a weapon; and the tactics that we evolved to exploit its employment for such a purpose not only in the defence of this country, but also in the protection of our bomber forces when attacking targets in enemy territory. I explained, too, that my theme would be devoted almost entirely to the application of these methods to air operations, and more particularly to those concerned with night bomber tactics of both our own Air Forces and those of the enemy.

* The term "radio" is used in its widest sense to embrace all forms of transmission of electric power through the ether, and so includes radar as well as all methods of wireless signalling.

This evening I propose to deal with the subject on somewhat similar lines but to concentrate more upon the effects produced upon air navigation by the application of our methods; and the manner in which we were required to use aircraft for our special operations.

I have chosen this mode of presentation with the main purpose of attempting to show why it is that our task in the Royal Air Force of providing air navigational aids for operational flying is likely to be more intricate than that confronting the designers of radio aids for purely peace-time purposes. There can be but little doubt that the use of radio counter-measures, introduced for the first time with such telling effect in the last war, will be a prominent feature in all future large-scale conflicts between nations, particularly in air warfare. Now that radio has assumed so important a rôle in warlike operations and is likely to play an even greater part as war becomes progressively more scientific, it is only to be expected that one side will do all within its power to deny to its opponents the benefits to be derived from the use of radio. In short, the science of radio counter-measures has come to stay

and must in future be regarded as an important weapon of war. Thus we in the Services are confronted with two new problems. First, we must assure that any radio system we use to further our war aims must be as impervious as possible to enemy interference; and secondly, we must continue to develop, and have ready for use in the event of emergency, methods of countering any radio device which might be used by an enemy.

2. THE VALUE OF RADIO COUNTER-MEASURES.

There are two possible courses open to us to achieve the first of these aims, both of which we shall require to follow in the event of further hostilities. The first is the obvious one of making our radio devices as "jam-proof" as possible; the second is to have ready up our sleeves alternative devices which, while giving the same service, would require a completely different countering technique. These indeed are the more obvious factors likely to affect the design of radio navigational aids in the fighting air services.

During the next few years we shall undoubtedly see the perfection of flying and landing aids to a degree that will enhance considerably the safety of peace-time aviation. If, however, these aids can be readily crippled by deliberate interference they will not be very useful, for example, to our bomber aircraft in time of hostilities—and the last war showed very clearly indeed that a force of night bombers cannot produce their maximum effect unless they have radio aids to guide them to and from their targets, and to locate their objectives.

Neither will it be possible for our bombers to operate at all unless we can ensure the safety of their bases and the immense industries that maintain them. We have to prevent the enemy from attacking us from the air with impunity—and one way of rendering the enemy's task more difficult is to deprive him of the use of his radio means of navigation and target-finding. Thus not only do we require radio counter-measures for offensive purposes but also for defence. This, then, is the second of the aims to which I have just referred.

Consideration in the abstract of such problems as these is not sufficient; we require positive proof that the assertions I have made are practical. Fortunately, the recent war provides us with convincing means of proving their veracity, and I propose to devote the greater part of this lecture to the illustration of the value of radio counter-measures by describing a few of the many and varied operations of this nature that we undertook during the course of the war.

The history of radio counter-measures, or R.C.M., to use its short title, falls conveniently into two distinct phases—the Defensive Phase and the Offensive Phase. My intention is to deal with them separately, but to devote rather more time to the offensive phase since it is more directly concerned with the employment of our own aircraft.

3. EMPLOYMENT OF RADIO COUNTER-MEASURES.

THE DEFENSIVE PHASE.

The defensive phase proper began soon after the invasion of the Continent by the enemy in 1940. By reason of their having occupied the coastal areas of Northern France and the Lowlands, the Germans were able to erect a large number of radio beacons and navigational beam stations within close distance of our country. These constituted a serious threat to us when, after the defeat of the Luftwaffe in the Battle of Britain, Goering turned his attention to night attacks. To add to the danger, we had not at this time perfected our night defences to anything like the degree that they later attained. The German air crews, however, were but poorly trained in navigation by night, and so depended to a great extent on their radio navigational aids to enable them to locate

their targets in this country, attack them, and then find their way home again. Their dependence on these aids was the Achilles heel in their plan and we decided to exploit it quickly.

Unfortunately, we were not in a position to take full advantage immediately of this chink in the enemy's armour, for we had neither the apparatus nor the requisite trained operators to enable us to begin operations on a large scale. We did possess, however, a band of enthusiastic and ingenious individuals who quickly got down to the job. Fortunately, the potentiality of R.C.M. as a defensive weapon was readily appreciated by those in the highest places of authority, such as the Prime Minister and the Chief of the Air Staff, and such eminent scientists as Lord Cherwell and Sir Henry Tizard. As a result, immediate and effective support was forthcoming which meant that we were afforded every possible facility to put our plans into execution with the least possible delay.

At the outset two pressing problems claimed our attention—first, to deny to the enemy the uninterrupted use of his medium frequency beacons and secondly, to deter him from riding into this country at will, along his navigational beams. The solution of both problems involved the conception of new techniques and the invention, development and production, of special apparatus in the minimum of time.

The M.F. beacon conundrum was solved by the Radio Engineering Section of the G.P.O. The technique consisted in picking up the enemy signals at selected sites in this country and causing the received signal to trigger off transmitters tuned exactly to the frequency of the enemy beacon, thus ensuring perfect synchrony.

The nature, and the extent of the effect produced on the airborne German W/T operator when endeavouring to obtain bearings, varied with his position relative both to his own beacon and to ours, but in any event not only was he unable to get a true bearing, but he was rarely able to tell whether the beacon signals that he could hear were, or were not, being interfered with by us. Thus the German air crews eventually came to mistrust the readings that they got from the very extensive system of "beaconry" established by the enemy with so much expenditure of effort, money, man-power and material.

Although useful for homing purposes when undisturbed, the German beacon system was too inaccurate, particularly at night, for target finding, despite the fact that the Germans were attacking large area objectives such as widely dispersed industrial centres and big cities. So, for greater accuracy, the enemy resorted to the use of long-range V.H.F. beams of the dot-dash type employed with standard beam-approach systems. These had a useful range of some 250 miles so that by erecting transmitting sites along the continental coasts opposite our shores, he was able to cover a large extent of this country.

The method adopted was to cause the beams emanating from two transmitting sites separated by a distance of the order of 100 miles, to intersect over the target. All the pilot had to do was to follow one of the beams and let his bombs drop on passing over the point of intersection of the other. The Germans claimed an accuracy of about 500 yards at a range of some 150 miles for this simple method—a degree of accuracy which was adequate for them when attacking a large town, or any region of London and its suburbs.

This system then constituted a grave menace to us, particularly as it enabled the enemy bombers to find their targets at night irrespective of the visibility conditions. The obvious counter-measure would have been to have flooded the whole of the vulnerable part of this country with intense jamming signals. This, however, we could not do as we had nothing like the requisite number of high-

powered transmitters needed for a task of such magnitude. We could, however, dispose our limited number of transmitters along the tracks usually followed by the beam-flying enemy bombers and site our relatively low-powered jammers where they would produce their greatest effect. Even then we knew that our jamming would not be strong enough to obliterate the enemy's beam signals, so we adopted the more subtle method of superimposing upon them signals of our own which were made to sound exactly like his. Instead of hearing only his own signals, the enemy then heard a number of similar signals from which he had to make his choice.

As in the case of the beacons, mistrust was quickly engendered—a feeling which was enhanced by the enemy acquiring two erroneous impressions which rapidly spread throughout his bomber squadrons. First, he thought that we were deviating his beam and secondly, that we were employing night fighters to patrol along his beam to catch him on his way to the target—both disheartening notions that did much to discourage his beam fliers at night and so made them less inclined to press home their attacks.

Gradually, as our R.C.M. operations grew in extent and improved in efficiency, the German Air Staff began to realise that the profitable results they expected to achieve from their night bombing activities were not forthcoming on anything like the scale that they had hoped. Although our defences were not as yet taking a heavy toll of the raiders, the Germans found that their losses due to errors of navigation, particularly in bad weather, were increasing and that frequently serious mistakes were being made by their bombers in the location of targets. Although some of our towns suffered badly, time and again the damage caused was not commensurate with the weight of attack; and the number of bombs wasted in open country seemed to be on the increase.

The necessity for a more accurate method of target location became vital and to meet this need the Germans introduced a novel and complicated system of beams for use by a specially trained unit of pathfinders. For a period this new method met with some measure of success but it was not long before we were able to mount an extensive system of counter-measures which did much to blunt the edge of this latest instrument.

Later, the Germans introduced yet another beam method working on a principle entirely different to the previous two. This we found more difficult to tackle than its forerunners, but by now our counter-measure organisation had got into its stride and so we were quickly able to make the enemy realise that the useful life of his latest device was likely to be short, with the result that it was never used by him on a large scale. By this time it had become apparent that the German Air Staff were beginning to lose faith in their radio aids, and were no longer so ready to give their support to inventions that appeared to them not only to be ineffective in assisting their night bombers, but seemed also to have the disadvantage of deluding their air crews and of serving to give us timely warning of impending attacks.

To add to their discomfiture our air defences were now becoming formidable and were beginning to exact a heavy toll from the marauding bombers. Then followed the decline of the night bombing campaign against this country, which marked the failure of Goering to atone for his defeat in the day battle of Britain by attempting to reduce us by night attacks.

The radio navigational aids in use by the enemy which I have mentioned, by no means represent the total of the systems that he employed in his attacks on this country. There were others, all of which called for attention on our part as, step by step, our defensive R.C.M. organisation grew into a vast system involving the employment of many men and much material and the devotion of considerable scientific and

engineering endeavour. Experience of great value was gained during this period which later was to be put to good use when our turn arrived to deliver night attacks in heavy strength upon the enemy.

4. THE OFFENSIVE PHASE.

We now come to the second phase of our R.C.M. operations—the offensive phase.

About the middle of the war, when they realised that they were going to be subjected to heavy bomber attacks on an ever-increasing scale both by our Bomber Command and by the United States Army Air Force, the Germans resolved to devote the greater part of their air power to the defence of their territory. Their radio scientists and engineers had made tremendous strides in the perfection of their air defences and slowly, but surely, Bomber Command's losses began to mount as the intensity of their night attacks increased. We were warned by our scientists that if this rate of improvement of the German defences continued, our night bomber forces would meet with such crippling losses that it might not be possible for us to continue our operations—certainly not on the scale which it was hoped to achieve.

We were not slow to realise that a large proportion of our losses was indirectly due to the enemy's radar early warning and raid tracking devices and his wireless-controlled night fighter system. Radar, too, was becoming effective in the control of his searchlight and A.A. defences. We were convinced that, by neutralising to an appreciable extent the radio aids that the enemy was employing as an integral part of his defence system, we could materially assist our bombers to keep their loss-rate within safe limits. Bomber Command did much to help themselves in this direction by so planning their tactics that the enemy were given the greatest possible trouble in using their radar to track our aircraft, and to gain knowledge beforehand of our likely routes and targets.

Thus our aircraft were concentrated in time and space when attacking their targets so as to saturate the radar defences; zig-zag routing was introduced so that the enemy could not guess the likely target by observation of the general trend of approach; and simultaneous attacks were made on targets in different parts of the country in order to deter the Germans from concentrating all their available night fighter forces on any one raid. Such stratagems as these, and there were many more, usually resulted in effecting a decrease in our losses, but not for long. The enemy was quick to reorganise his defensive tactics to meet each new trick as it was played.

It became obvious that a more positive form of protection against his radio defences was required. Various R.C.M. devices were fitted into the aircraft of the main bomber force and undoubtedly produced an effect, but this process was not wholly satisfactory for several reasons. The crews of our aircraft were usually too busy at the most critical periods to be able to devote sufficient attention to the operation of the apparatus, some of which required the undivided occupation of a specially-trained operator: carrying the instruments meant a lesser weight of bombs or petrol; and, probably more important than all, jamming transmissions made in operational aircraft were liable to assist the enemy in tracking our main forces, and to enable the enemy fighters, some of which were fitted with apparatus specially designed to home on to such transmissions, to intercept more easily the individual bomber aircraft. Thus it became clear that we required special R.C.M. air units that could be specifically employed on the task of interfering with the electric ears and eyes of the enemy.

Accordingly, in the winter of 1943, it was decided to form within Bomber Command a special Group whose main rôle was to afford protection to our night bomber forces during their attacks on targets in enemy territory. The new formation, known as No. 100 Group, was to comprise a mixture of heavy

bomber aircraft which in place of bombs would carry R.C.M. apparatus and the specialist crews trained in its operation; and night fighter aircraft, also fitted with special apparatus, whose task it would be to seek out and destroy the opposing night fighters.

The task of organising and fitting out the squadrons of this new Group and training its specialist personnel, was pushed ahead with all possible speed and drive. They could not go into action for some few months since their aircraft had to be fitted with the special R.C.M. apparatus much of which had to be designed, developed and manufactured *ab initio*.

In the meantime, the losses incurred by our night bombers continued to mount, and might well have reached a prohibitive level had not Bomber Command obtained a welcome respite by the introduction of the simplest, and yet most effective, countermeasure ever produced during the war. "Window" was the cover name which we bestowed upon this new device and it consisted merely of thin strips of metal or metal-covered paper which, when thrown from an aircraft, produced spurious echoes upon the enemy's radar tubes while slowly fluttering to the ground.

A packet of this paper weighing but a few ounces could produce an echo similar to that made by a four-engined aircraft. By causing each aircraft in a formation to throw out a number of these packets at short intervals, an effect equivalent to the presence of thousands of aircraft was produced upon the radar watching systems on the ground, and eventually ended in so cluttering up the radar picture that the system was rendered temporarily useless for the purpose of tracking and counting aircraft. "Window" also interfered to some extent with the radar apparatus carried by the German fighters for intercepting our bombers and also caused trouble to the enemy's searchlight and A.A. gun radar director systems.

"Window" was first used by Bomber Command in July 1943 in a series of attacks against the heavily defended port of Hamburg. Its effect was immediate and catastrophic as far as the enemy defences were concerned. For some months past we had been trying to reduce Hamburg, but it was so well defended that the effective damage caused by our bombers was not great and our casualties had been heavy. With the help of "Window" we were able to smash up Hamburg within a week with but very small losses indeed. During this series of attacks our casualties did not exceed two per cent. of the forces despatched, with the exception of one night when our losses were somewhat heavier because of unexpected bad weather over the North Sea.

Once the secret was out we were able to take rapid strides in the perfection of this device and the production of the material required. Up to then, although we had discovered the effects of "Window" against radar many months before it was first used operationally, we had been severely hampered, because of the need for security, in conducting live experiments; and in our efforts to produce sufficient material for sustained use by the whole of our bomber force. With the lifting of the secrecy ban it became possible to improve greatly the effects produced, by designing "Window" of various patterns to give the optimum effect against specific components of the German radar equipments. We were able, too, to try the effects of "Window" ejected at various heights and in varying conditions of wind, and to discover by actual experiment the most effective rate of discharge, and the amounts needed for any particular type of operation.

It will be realised that this weapon was two-edged. It was so simple to produce that once the enemy had learned the secret he might have employed it just as effectively against our own radar defences in a very short time. Therefore we had to take two important factors into consideration before deciding to use it against the enemy. Either we had to be sure that the enemy's offensive

air strength had deteriorated to a sufficient degree that even if he did employ it against us in this country the effects produced would not have been important; or else we had to make our radar sufficiently "Window-proof" to ensure that our defences would not be completely upset if the enemy did use the device. Eventually the moment came when it was considered that both requirements were reasonably satisfied.

The stage had been reached when the enemy found that his resources were insufficient to maintain an effective defensive system simultaneously with a strong air striking force. The defence of his own territory had now assumed the greater importance in his eyes and he decided to concentrate upon strengthening his air defences at the expense of his bomber forces. At the same time our scientists and radar experts had devised means of ensuring that our radar would not be entirely put out of action by "Window." Judging the opportune moment for launching "Window" was a major decision, and the Prime Minister himself gave the final authority to "open the Window"—as he put it picturesquely.

The sudden introduction of "Window" undoubtedly came as a complete surprise to the Germans and was the cause of great devastation to his defensive system. The considerable drop in our casualty rate raised still higher the morale of our splendid air crews and had the effect of spurring them on to even greater efforts. But it was not to be expected that, once the period of surprise was past, "Window" would continue to remain as effective as when it was first used.

Although for the remainder of the war "Window" continued to be a great embarrassment to the Germans, the Luftwaffe were eventually able, by readjusting the methods of control and the tactics of their night fighter forces, to overcome to some degree the deleterious effects that their radar system was now having to endure. Moreover, their radar scientists and engineers by dint of feverish activity managed in the end to counter to some degree the damage that "Window" was causing to their equipment and it was found possible also, to train some of the better ground radar operators to read through the interference when not too intense.

Gradually our loss rate again showed a tendency to mount, but by now the new R.C.M. Group was starting to make its weight felt and, as its resources and experience grew, once again we saw a decline in our casualty figures. This time there was to be no subsequent increase and by the end of the hostilities in Europe, when Bomber Command had intensified the weight of their attacks to a degree never before realised, our casualty rate was lower than at any other period of the war.

There were of course other factors which contributed to this satisfactory state of affairs. For example, the withdrawal of the enemy from France and the Lowlands deprived him of the ability of gaining early warning from the radar system which had hitherto been liberally deployed over the areas commanding our approaches to Germany from the westward. Then again the enemy was faced with a serious shortage of aviation fuel.

Nevertheless now that the enemy had concentrated all his defences in a much smaller area, and was giving first priority to his fighters for what petrol still remained in his possession, the cracking of the defensive nut was still a formidable proposition. The night fighters were still the gravest menace to Bomber Command, and the cause of the greater proportion of its casualties, and so it was mainly against the fighters that the activities of 100 Group were directed.

The new Group had three main rôles in its task of lessening the danger from the German night fighter force. These were to employ night fighters of our own to harass those of the enemy; to provide heavy aircraft fitted with R.C.M. apparatus with which to mask or dupe the radio aids in use by our opponents; and to employ aircraft to gain first-hand information of their radio aids and the methods they were adopting in their

employment. Later, as experience in these unique forms of operation grew and more aircraft and trained crews became available for this work, many novel tactics were evolved and much new apparatus was developed—all designed in general to upset the enemy's night fighter organisation which up to this time had virtually had a free run for its money.

The task of our offensive night fighters was a difficult one, calling for considerable technical skill and supreme qualities of courage and determination on the part of the crews manning them. Their areas of operations were too distant for them to be controlled from the ground as was done with the defensive night fighters in this country. Theirs was the dangerous task of flying hundreds of miles in darkness, frequently through extremely bad weather to seek out their opponents and then engage them in combat. Some met the bombers *en route* and escorted them to their targets: some were despatched to marshalling points over enemy territory where the German fighters were likely to congregate before being sent to intercept our bombers; and others were allotted the task of patrolling specially selected aerodromes on the continent which we anticipated would be used by the enemy night fighters on any particular night. These British night fighters were crammed with "black boxes" all of which had to be operated by the pilot or his navigator, and the purpose of which was to ensure accurate navigation and to enable the crew to home upon enemy ground beacons, or even on the interception apparatus that the enemy fighters carried in their aircraft to engage our bombers.

The number of enemy aircraft destroyed and damaged by our offensive night fighters was considerable, but probably the moral effect produced by the mere fact of their presence was even more telling than the material damage caused. Up to now the enemy night fighter had had but a single preoccupation—to seek out and destroy the relatively large and slow target presented by the British four-engined bomber. Now the German had continually to be looking over his shoulder in the fear that he was being stalked.

The rôle of the night bombers allocated for purely R.C.M. purposes was entirely different. The system of loose control of his fighters developed by the enemy after "Window" had wrecked his close control system, depended for its success upon two factors— an efficient early warning system and the ability to plot confidently the track of our bombers while approaching and leaving their targets.

In 1943 the enemy was well able to do both these things. His early warning system enabled him to plot the approaching bombers while they were on their way at ranges up to about 200 to 250 miles—in some instances he was even able to see them forming up over this country. Once the raid had crossed into his territory he was able to track its progress with certainty. The assistance that such information afforded to his defence organisation was enormously valuable and by March 1944 our losses were reaching alarming proportions. Carefully planned bomber tactics certainly did much to confuse the enemy's ground controllers, but their raid reporting and early warning systems remained virtually intact.

The job of the R.C.M. aircraft of the new Group was to impair these systems, and in doing so they had to tackle all the links in the chain of defence. Consequently we developed a jamming screen for the purpose of blinding the enemy's early warning system and so preventing him from obtaining information of our approach until we were in close proximity of his chain of warning stations. Then when our bombers were over his territory, and their presence consequently revealed, a number of R.C.M. jammers accompanying the main force interfered with the radar tracking systems and the R/T channels over which the ground controllers gave directions to their fighters in the air.

Inevitably, it was not possible by these methods to prevent all the night fighters from

finding the huge masses of bombers, particularly after our crews had announced their presence by bombing their targets. The next stage, therefore, was to make the task of the German night fighters as difficult as possible by jamming the airborne interception apparatus that they carried.

All these methods in themselves could not be expected to be wholly successful everywhere all the time. No matter to what extent we deprived the ground control, and the night fighters, of the use of their electric eyes and ears, we could never be certain that a considerable number of free-lance fighters would not find their way into the enormous bomber masses. The only way open to us to lessen this menace, and it was becoming a grave one since the more we interfered with the enemy's control organisation the more he tended to fall back upon free-lance tactics, was to induce the enemy to move his fighters to areas remote from that of the target, or else to get his fighters airborne at the wrong time, and in the wrong place.

As soon as we were able to increase the strength of the R.C.M. Group sufficiently to enable us to employ a number of its aircraft on decoy missions we found it possible to deceive the enemy in this manner. Many ingenious and varied plans were worked out to this end and time and again were successful, in varying degrees, in diverting the enemy's fighters away from our main bomber forces.

I have not the time to describe all the means we employed, so I will limit myself to a brief description of a few of them.

Perhaps the most successful of our deceptive methods was the employment of what we termed "spoof" bomber forces. We discovered that we could make a small force of heavy aircraft, usually of the order of a dozen to twenty in number, look like a large force of some hundreds or so as seen on the enemy's radar presentation. This we did by means of "Window."

While over enemy territory a main force would eject "Window" at a predetermined rate, say, two packets per aircraft per minute. This would give a characteristic blob on the German radar. Our "spoof" force would be so spaced as to occupy an area similar to that of the main force, but would eject "Window" at a very much higher rate—the product of the number of aircraft and the number of window packets ejected per minute being made roughly the same for both main and decoy forces. This gave rise to an equal degree of "Window" infection by both forces, and consequently similar blobs appeared on the enemy's cathode-ray tubes.

By this means we could mount simultaneously with the main raid one or more spoof attacks in areas different from that of the main target. Thus it would be that the enemy would see emerge from the jamming screen a number of blobs which to him represented heavy bomber forces. Each would appear to be travelling along a different track, and each track would probably be pointing towards a vital target.

The enemy had now to guess which was the real threat if he wished to concentrate all his fighter effort against it; or else play for safety and divide his fighter forces up to meet each of the threats. Sometimes he chose the first alternative and, if his guess was wrong as often it was, our main bomber force escaped the weight of his night fighter attacks. If he chose the second, the weight of attack against the main force was considerably lessened.

Another method was to include the "spoof" aircraft in the main force for a period after breaking through the jamming screen, thus forming a single blob. This would be tracked by the enemy across his territory and his fighters would be assembled in an area through which he guessed the bomber stream would pass. However, he would suddenly see the blob split up into several, each proceeding in a different direction. Some of these blobs were real, and some were decoy, and as often as not he was unable

to differentiate between them until the bombs began to fall.

A typical example of this form of operation, and one which achieved conspicuous success, occurred in October 1944, when Bomber Command planned to attack Duisburg with 1,000 heavies and Brunswick with a force of 200. It was anticipated that the Duisburg force if carefully routed and screened to avoid early detection until the latest moment should, by reason of the shallow penetration into enemy territory, escape heavy casualties. The Brunswick force, having to penetrate very much farther into enemy territory, was likely to run grave risks. A "Window spoof" was therefore despatched with the Brunswick force and broke off during the approach to strike at Mannheim. The enemy took the Mannheim threat as the real one and concentrated all his available fighters to meet it, almost completely ignoring the Brunswick raid. When he found out his mistake it was too late to re-deploy his fighter forces.

A further fruitful means of employment of the "spoof" forces was the mounting of raids at times when the main force was not due to operate. Towards the end of the war when the enemy was running short of petrol and was striving his utmost to bolster up the flagging morale of his fighter crews, this process of attrition caused him considerable aggravation and despondency. For example, on the night of 16th-17th August 1944, Bomber Command launched heavy attacks against Kiel and Stettin. On the following night the enemy was given every reason to believe that Bomber Command was going to repeat the dose in the same area. But this time the enemy was ready, and as soon as the familiar blob appeared he deployed no less than 12 fighter squadrons against the attackers, but no bombs fell in Germany nor did any victories to the defenders. On the next night there came another repeat performance, but this time the enemy was not going to be caught and the threat was left entirely unopposed—and Bremen received a severe pounding from our bombers.

Later in 1944, Bomber Command were employed for a time almost exclusively upon attacking targets in the Ruhr. The enemy soon realised this and adopted the policy of keeping a mass of night fighters airborne over the Ruhr area as soon as he realised that bomber attacks were imminent, so that whatever target was attacked his airborne fighters had but a relatively short distance to travel to intercept our bombers. "Spoof" raids away from the Ruhr gained no success, for the enemy was determined not to be diverted.

A new form of tactics was therefore evolved for the "spoof" forces. They accompanied the van of the main force and just before arriving over the Ruhr area they fanned out, "Windowing" at the highest possible rate, and so infecting a large area into which the main force proceeded. Once in the cloud our bombers' tracks were concealed and so did not reveal to the German ground control the particular area which was to be the object of their attention. Thus until the bombs began to fall the Germans were not able to give the requisite instructions to their waiting fighters. By the time the fighters did get to the target area the attack was probably over and the bombers on their way home on a different route, whose track was once again hidden in the "Window" cloud.

As time went on and we could gauge the results obtained by stratagems such as these, we were frequently able to throw the elaborate control system which the enemy had so painstakingly built up, into a state of great confusion. Every new tactic or device introduced by Bomber Command to improve its bombing efficiency found its counterpart in the operations of the "spoof" forces, so as to ensure that the enemy should not be provided with a means of readily differentiating between the real and the decoy forces. For example, the tactics of the Pathfinders in

marking the targets before the main force attacked was liable to give the enemy a short, but nevertheless valuable, period of time in which to get his fighters to the threatened area. Dummy pathfinder methods were therefore introduced into the decoy attacks.

Then again it was the custom of Bomber Command to make, on some occasions, a preliminary attack on a target for marking purposes. To simulate this procedure an American heavy bomber Group, who had learned the Pathfinder tactics, was attached to the R.C.M. Group and rendered most valuable and courageous service by leading the decoy forces and dropping marker flares and bombs on the diversionary targets.

A remarkable feature of the operations of these decoy forces was the low rate of casualties that they sustained, despite the fact that they were the scapegoats of Bomber Command. Theirs was the job of stirring up hornets' nests from which they had to slip away as soon as they were in the thick of the trouble that they had deliberately provoked. At a time, for example, when Berlin was seriously threatened and was known to be heavily defended, these small forces of heavy bombers, in which each component was often miles away from his fellows, would leave the main bomber force and proceed on their lonely way towards the capital into the thick of the trouble that they knew was waiting for them there, but with the knowledge that in so doing they would contain enemy fighters that would otherwise be available to be sent to the scene of the main force's activities.

The fact that they were so often successful speaks volumes for the superb navigation of the air crews and their determination to do their job despite the dangers that they knew lay ahead. Every man was an expert, highly trained and with a thorough knowledge of his difficult and complicated tasks—tasks in which they did not have the exhilaration of being able to see the effects of their work during their actual operations. These they did not know until the following morning when the losses of the main forces and the results of the previous night's attacks were announced. They did know, however, that they were instrumental in saving the lives of many gallant bomber crews and that their mere presence on an operation imbued many of the crews of our operational Groups with the comforting feeling that they were being looked after, and that their chances of survival were consequently much enhanced.

It will be readily understood how necessary it was to maintain close secrecy in regard to our R.C.M. activities during the period of the war. One of the most important factors in the use of R.C.M. is to make the fullest use of surprise, particularly in decoy operations. It was important that the enemy should gain no inkling beforehand of the extent to which we were aware of his intentions and of the preparations which we were making to upset his new devices and tactics. It frequently happened that we were able to apply a certain counter-measure in a way not immediately apparent to the enemy, and mysterious happenings are likely to produce a profound psychological effect upon air crews—a state of affairs which is readily understood bearing in mind that the crews, particularly at night, work in an atmosphere of extreme tension while engaged on their dangerous missions. By a careful study of this factor it was often possible to take advantage of the moral effect in order to enhance greatly the results produced by our counter-measure activities.

We found it strange that the Germans never made any really serious attempts to develop R.C.M. on their side. The efforts they did produce were spasmodic and lacking in organisation, and never on a sufficiently large scale. We were often amazed that we were allowed for so long the use of our radio aids to navigation and blind-bombing, which did so much to increase the effectiveness of our night bomber raids, particularly towards the end of the war when Bomber Command were systematically destroying one by one the

centres of industry and vital keypoints in German territory.

We learned after the war that the enemy realised too late the value of radio counter-measures. When he did appreciate their full value he found that he had neither the resources nor the skilled experts to spare from the overwhelming task of rendering his own radio systems immune from the dangerous effects of our counter-measures. This, then, was one of the principal reasons why so many of the navigational and bombing aids that we introduced enjoyed periods of immunity from enemy interference far exceeding our expectations, with the result that by the time that the enemy did eventually succeed in causing a serious degree of disturbance to any particular radio aid, our scientists and engineers had had time to develop, and introduce, an improved device, probably working on an entirely different principle, calling for a completely different form of counter-measures.

CONCLUSION.

I do not propose in this lecture to talk about likely future developments of this new science of radio counter-measures. It will be apparent that now radio has assumed so important a place in modern warfare, it is likely to play an even greater rôle when we arrive at the stage of fighting with remotely-controlled projectiles capable of carrying tremendously powerful explosives and of being aimed accurately at targets over vast ranges. It may well be that some form of radio counter-measure will be the most effective means of defence against such weapons—the future will tell.

In the meantime the last war has shown us the writing on the wall—that a nation possessing the ability to exploit the valuable uses to which radio as a weapon can now be put will be endowed with advantages which an opposing nation can only hope to neutralise by a vigorous and carefully-planned radio counter-measure organisation. In brief, in any future conflict between highly developed powers there will inevitably be a "War in the Ether." It is for this reason that preparations for such a war are likely, as far as service flying facilities are concerned, to introduce an important factor in the development of radio navigational aids which would not normally be required to be considered by the designers of such aids needed for purely peace-time civil flying.

DISCUSSION

Sir Frederick Handley Page, C.B.E. (President, Fellow):—When they heard of all that had been done in waging the war in the ether, they began to realise that it was worth while putting up with all the tremendous inconveniences caused by modifications to wireless apparatus, with all that they entailed, to which aircraft manufacturers were subjected during the war. Changes had been taking place continually; just as one set of specifications had been produced, there would be further modifications, involving another set, then another, and so on. Had the manufacturers been in possession at that time of the information contained in the paper, they would have appreciated that those changes were really worth while.

How could radio screens be provided along the coasts, to prevent the Germans being able to "see" what was happening on this side of the screen? It seemed a fantastic idea that, in the attack on Germany, they put down a curtain and when they wanted the actors to appear on the stage, Air Vice-Marshal Addison had pulled back the curtain and out had come the actors! It was an extraordinary conception, and he would like to know more about how it was done.

Again, how had the experts found out where all the German stations were and how

had they found out the way in which the German fighters were deployed? He wondered whether the Germans had attempted to do the same kind of thing that they were doing in this country; presumably, from what was stated in the paper, that was not so.

It would be of great interest to hear what Air Vice-Marshal Addison's opposite numbers, from the enemy side, had to say about the successes he had achieved against them.

If there were one most important underlying feature in the radio warfare, and in the whole of their radio operations, it was the extraordinary collaboration which had existed between the scientists and the R.A.F. It was extraordinary that in No. 100 Group there was such close co-operation between those who were developing on the scientific side and those who were actually employing the equipment in the air warfare. It would be interesting to hear from Air Vice-Marshal Addison what were the conditions on the enemy side. So far as he knew, the conditions there were just the reverse, in that the German Generals would not believe any of the scientific people, and were prone to ask what was the use of those people, anyway; they were certain that what had been done had been written in a book by a German General a hundred years or so ago!

Group Capt. E. Fennessy (Director, The Decca Navigator Co. Ltd.): He was particularly interested to hear the description of the use of radio in preventing the enemy from attacking this country and in preventing the successful interception of R.A.F. night bomber forces over Germany, for his own work during the war was concerned with another application of radio, that was the use of radar in attacking the enemy and in guiding our bombers so that they were able to deliver their bombs with precision on the target.

The enemy had tried to deny them the use of radio, but compared with the denial they had imposed on him, the results of his effort were insignificant. In general they had a good six months of grace between the introduction of any new radio weapon and the time when the enemy began to deal with it effectively. This should be contrasted with the work of 100 Group whose experts were aware immediately of any new technique employed by the enemy and usually began to deal with it effectively within a matter of days. There were great lessons to be learned from the last war in studying the problem of any future war, and one of these was the great need for any nation engaged in a war to have a thorough appreciation of the potential danger of radio. If the Germans had realised the extent to which the radio weapon was being employed against them, they would have saved the Ruhr—but this they failed to do.

Great use had been made of radio as a guide to bomber forces and in many other fields of the R.A.F.'s activity. After listening to Air Vice-Marshal Addison's description of the work of radio counter-measures in 100 Group, it would be appreciated what a tremendous technical organisation was required to prevent the enemy's successful attack on Great Britain and to deliver their own attack against him. They had been concerned with dropping thousands of tons of bombs on the enemy. In any future war the problem would not be the delivery of tens of thousands of high explosive, but probably of placing a few hundreds of tons of bombs at the right points in the enemy territory.

Vast as the technical organisation of the last war had been, that required to drop only a few hundred bombs in any future war would be even greater and they might well see the whole organisation of the Royal Air Force turned upside down to become a great army of technicians with particularly strong emphasis on the radio side, concentrating on the single problem of delivering missiles effectively against the enemy.

But there were other considerations. The

last war was fought at short range which favoured the use of radio; at a range of 250 miles, which was the distance of the Ruhr from England, they could achieve a high accuracy in placing bombs, but if they considered the problem of a global war demanding precise navigation or missile control, then radio as they knew it during the last war would not achieve the accuracy required. In general, very high frequencies were necessary to achieve accuracy, but high frequencies could only be employed at short ranges, and the problem that would confront the radio technician of the future would be to achieve accuracies of the right order at global ranges. This was no easy problem, particularly when the aspect of radio counter-measures was taken into consideration.

The use of radio as a navigational aid or missile guide demanded an external intelligence. Either radio signals had to be transmitted to the aircraft or missile, or alternatively, it had to transmit radio signals which, reflected back from the earth, provided it with the necessary intelligence. Radio was not a self-contained thing and, since it depended on external intelligence, it was always possible for the enemy to jam or simulate this intelligence in a way similar to that described by Air Vice-Marshal Addison. Air weapons of the future must tend to be self-contained with regard to the means by which they were guided to their target and this would probably lead the research work into many new and novel fields. The opinion of Air Vice-Marshal Addison on whether this would lead them away from radio would be interesting.

Mr. S. Scott Hall (Ministry of Supply, Fellow): How would radio counter-measures be affected by the speeds and altitudes which it was anticipated would be achieved in the next war, supposing that this occurred within the next 10 or 15 years, *i.e.*, before the disappearance of the piloted aircraft?

Miss A. Kennedy (Companion): Had radio been used, and if so to what extent, as a means of protection against the German V1 weapons, such as by altering the course of those weapons?

AIR VICE-MARSHAL ADDISON'S REPLY

The answer to the President's question as to how they knew where the German stations were situated was a long story. In war, each side did its best to find out the battle order of the other. They were helped by the Germans who, when they got particularly confused, used to talk a lot in plain language to their fighter pilots during their defence operations. Naturally, they listened to this chatter and that greatly helped them. Of course, information was also obtained by other means which all helped to form a general picture. By listening to the directions given to the German fighters they could often plot the progress of their own forces and so estimate when they had reached their target. By this means they could tell, too, the direction in which the German fighters were being sent, and so frequently guess their point of origin. Thus Bomber Command could sometimes be warned of the danger spots which it was advisable for them to avoid.

He had had an opportunity of meeting some of his opposite numbers after the war, and learned that their technicians frequently told the German Air Staff of the opportunities they were missing in not devoting more attention to R.C.M. He believed Goering was the great stumbling block, for he did not seem to know what was going on, and why the Germans were getting into so much trouble. On one occasion Goering had himself taken control during a night fighter operation, and had sent his fighters chasing right across Germany to the north, while Bomber Command was putting in a heavy

attack to the south, almost without any opposition at all.

He had had also an opportunity to examine the German system of fighter control, and was impressed at the extent to which the Germans had been duped by decoy raids and radio deception.

At the beginning of the war he believed that the relations between the German Military Staff and the scientists had been very good indeed, but at a later stage the German Staff seemed to have lost a lot of faith in their scientists.

His opinion was that for every new weapon of warfare there could always be found an antidote. Time and time again during the war they had been told that it was not possible to counter certain inventions; but it was rare, if ever, that an effective counter was not found. If scientists could produce a weapon which appeared to be unassailable, then they ought to be able to find equally clever scientists to counter its effects. The important thing was that the inventor and "counter-inventor" should not work in the same laboratory, but in separate laboratories.

It was true that with increased heights and speeds of aircraft towards the end of the war, their countering work was becoming more difficult, but with their increased knowledge and resources they should have been able to produce the necessary counter methods.

One mistake that could easily be committed was placing too much reliance on pure theory. Early on they had been told that the laws of propagation made it impossible for them to hear certain signals on the ground. They erected listening stations and they found that they were able to hear the signals they wanted as far north as Birmingham, whereas they were not supposed to hear them beyond the middle of the English Channel. These signals enabled them to determine the direction in which the Germans were laying their long distance beams when attacking this country. The Germans also knew these propagation laws and were presumably also most surprised when they realised that the R.A.F. was hearing their beams on the ground. By listening to these signals, the R.A.F. was able to follow quickly with their jamming transmitters the changes of frequency that the Germans used to make in an endeavour to avoid the effects of the jamming.

Although they were being told that there would be devices in the future which they would not be able to counter, he himself refused to believe it. If, eventually, they were threatened with long-range radio controlled weapons, he was sure that they should be able to counter them.

THE ROYAL AERONAUTICAL SOCIETY

Paper received October 1946.

PERFORMANCE CALCULATION FOR JET-PROPELLED AIRCRAFT

by

R. K. PAGE, B.Sc. (Eng.)., A.F.R.Ae.S.

Since taking his B.Sc. degree in Engineering at London University in 1935, *Mr. Page has been with Westland Aircraft Ltd. He served first in the Stress Office and is now on Performance and Project design work.*

INTRODUCTION.

An analytical method is developed for calculating the speed and climb performance of jet-propelled aircraft, given the drag and thrust data. A method is also given for dealing with the effects of compressibility and the results in a typical example are included to illustrate the form of curves obtained.

In the past, when dealing with aircraft driven by reciprocating i-c engines and propellers it has not been possible, even on the assumption of the available power being independent of forward speed, to evolve an analytical method of calculating the complete level speed and rate-of-climb performance of the aircraft, because the level speed equation is a cubic, for which there is no general solution, while even a constant speed propeller causes the thrust horse power in the region of the best climbing speed to vary with forward speed in some manner that cannot be expressed as a simple function.

For these reasons some graphical method has to be used which, although not presenting any special difficulty, is less convenient and rapid than a simple analytical method would be when only a part of the complete performance is required, *e.g.* the absolute ceiling, or the cruising speeds at one or two particular heights; and also the change in value of any of the fundamental parameters such as aspect ratio or wing loading usually requires a fresh start.

When we come to the simple jet-propulsion engine type a much more convenient condition exists, since the net *thrust* and not power (or thrust $\times$ speed) is practically constant over the flight speed range of the aircraft, so that the level speed equation is only a quadratic, which is easily solved by reduction to the usual "standard form." The known (constant) value of the thrust at any given engine speed and height also enables the conditions for and value of the best rate of climb to be directly calculated, as also, but with a slightly greater amount of approximation, may the cruising conditions of best air-miles-per-gallon of fuel and best duration.

The equations of speed and climb performance here derived have been found during the past few years to be of considerable use in estimating performances of jet-propelled aircraft. Although some of the expressions may appear somewhat involved there is considerable simplification in their use as several of the products of terms are constant for a given aircraft and all symbols such as C_D have their usual significance, while the assumptions made, such as thrust not varying with forward speed, specific consumption not varying with engine r.p.m., and aircraft drag being a simple quadratic function of lift coefficient, will have an effect on the accuracy of the final results well within that of estimation of drag coefficients etc. in the first place, at any rate in the early stages of a design.

As regards the two engine assumptions, the small error may be further minimised by taking the thrust, or specific consumption, appropriate to the known approximate aircraft or engine speed for the condition, *e.g.* cruising, climb or "all-out-level," under consideration.

No mention has been made of rocket-propelled aircraft as a class for which this method of performance estimation may be used, although evidently it is applicable, since the thrust of a rocket is constant not only with forward speed, but also very nearly so with height; any aircraft solely or mainly rocket-propelled will almost certainly operate at an angle of climb approaching the vertical so that the wing lift will be small. In effect the craft will be a projectile, while its level flight speed will be in the region of compressibility effects for which a special treatment is necessary.

The assumption of a constant value of C_{D_o} of course implies incompressible flow, since one of the most pronounced effects of compressibility that becomes evident in the region of the "critical" Mach number is a fairly sudden increase in drag coefficient of the aerofoil section.

Although almost any jet-propelled aircraft that is not under-engined will probably reach its critical Mach number at all-out level speeds, except perhaps near sea level, this does not completely negative the usefulness of the present method. It is at any rate of interest to the aircraft designer to know just how much speed he is losing from compressibility effects, while there are still the cruising ratings at reduced r.p.m., giving speeds that will probably be below the critical.

Besides the drag increase, compressibility effects may include appreciable changes of trim and also buffeting which may set a practical limit to the attainable level speed. Thus, at least until a fair amount of high speed tunnel testing has been done on the complete aircraft model, it is not unduly cautious to assume that the higher Mach number of level flight will be that at which the low speed value of C_D has increased by, say, 25 per cent.

For aircraft with very high thrust/weight ratios, such as interceptor fighters, the angle of climb will be very steep, and the basic assumption that lift equals weight will, by overestimating the induced drag, produce a slightly pessimistic value for the rate-of-climb. But, as in such conditions the forward speed will usually be high, the lift coefficient and hence induced drag will be low, so that the error is usually of second-order importance.

An exact method that may be used to produce a "polar diagram" of the performance, is to take for each height a series of angles of climb, and for each angle to equate drag to thrust and weight component along the flight path, and lift to component of weight normal to flight path, then by substituting the resultant value of $D/L = \frac{C_D}{C_L}$ in the equation for $C_D = C_{D_o} + KC_L^2$ to solve for C_L and hence speed V and vertical component $V \sin \theta$ (see appendix II).

An examination of the final expressions for speed, climb, etc. (appendix I summary) reveals certain fundamental characteristics differing from those of a propeller-plus-reciprocating engine aircraft. First, the top speed varies as the square root instead of the cubic root of the drag, so that a given change in C_{D_o} will produce one and a half times as great a change of speed on a jet as on a propeller-driven aircraft.

It is frequently required to find the variation of performance with all-up weight, particularly when, as with most jet aircraft, the consumable load, *i.e.*, fuel, forms a large part of the total. Unfortunately, neither the maximum speed nor the climb expressions give a simple form for the differential with respect to weight, and so re-calculation is necessary for a new weight. Since the jet aircraft will generally climb at a higher forward speed than the propeller-driven one, the effect of weight on rate-of-climb will be reduced. For the absolute ceiling (if it is

over 36,000 ft.) the simple law holds that the relative density is directly proportional to the all-up weight.

Turning to economical flying, instead of the classical result that the best range is obtained when the induced drag equals the parasite drag, *i.e.*, at maximum L/D, the condition for jet aircraft is that induced drag $= 1/3$ parasite drag, this obtains at a speed some 15 per cent higher. Theoretically the speed for best economy will vary as the square root of the weight, and the miles per gallon inversely as the square root, but this latter may be modified by the actual variation of engine specific consumption with both r.p.m. and forward speed. In general the effect of weight will be rather less than with the propeller aircraft for which m.p.g. varies theoretically as the reciprocal of the weight, but in practice as a rather lower power. The most striking effect is that of height, which for the jet aircraft will vary the m.p.g. as $\sqrt{\sigma}$, *i.e.*, double in value between 0 and 40,000 ft., or when variations in specific consumption are taken into account, vary at an even greater rate. Similarly the speed for maximum duration, *i.e.* minimum fuel consumption, instead of being that for minimum power required which is usually in fact beyond the flaps-up stall (and thus unattainable), is for the jet aircraft at the speed for best L/D, *i.e.* minimum drag, and again varies approximately as the square root of all-up weight. At first sight it would appear that the fuel consumption would not vary with height, since the thrust is constant, but again the variation of specific consumption has a big effect, the consumption decreasing considerably with height.

Jet engine data is usually presented in the form of curves of thrust and fuel consumption at various r.p.m. against height, a separate set being drawn for various forward speeds; it is usually worth while cross-plotting against both forward speed and r.p.m. for various heights, in order to avoid interpolation. An alternative form of presentation is a "grid" of specific consumption, lb./hr./lb. of thrust plotted against thrust, lines of constant r.p.m. and constant forward speed being drawn for a given height. In this form it is rather easier to gain an understanding of the reasons, for example, for the large variations in consumption and m.p.g. with height.

It is most desirable that for any project design of jet-propelled aircraft a complete performance investigation should be made, including such things as cruising performance over a range of heights and the variation of the whole performance with changes in weight, drag coefficients, etc., with the engine operating conditions kept in mind, so that the most suitable size and type of engine may be chosen for the aircraft design.

Appendix I.

JET AIRCRAFT PERFORMANCE.

It is assumed that thrust at constant height and r.p.m. does not vary with forward speed over the range of flight speeds; also that drag coefficient C_D can be expressed as $C_{Do} = C_{Do} + KC_L^2$.

T = Total thrust, lb.
V = Forward speed, m.p.h. (knots)
v = Forward speed, ft./sec.
$v_{C\,max.}$ = Maximum rate of climb, ft./min.
D = Total drag, lb.
W = All-up weight, lb.
w = Wing loading, lb./ft.^{2}.
S = Wing area, ft.^{2}.

$t = T/S.$
$q = \frac{1}{2}\rho v^2 \qquad C_L = w/q \qquad C_D = C_{D_o} + KC_L^2$
$K = C_{D_i}/C_L^2 = (1/e)(1/\pi A)$
A = Aspect ratio.
e = Aerodynamic efficiency.

1. MAXIMUM LEVEL SPEED (WITHOUT COMPRESSIBILITY).

Thrust = drag.

$$i.e.\ T = qS(C_{D_o} + KC_L^2)$$
$$= qS(C_{D_o} + Kw^2/q^2)$$
$$\therefore Tq/S = C_{D_o} q^2 + Kw^2$$
$$\text{or } C_{D_o} q^2 - tq + Kw^2 = 0$$
$$\therefore q = \frac{+t \pm (t^2 - 4C_D Kw^2)^{\frac{1}{2}}}{2C_{D_o}}$$
$$v^2 = \left(\frac{2}{\rho}\right)\frac{t \pm (t^2 - 4C_{D_o} Kw^2)^{\frac{1}{2}}}{2C_{D_o}}.$$
$$V = \left(\frac{2}{\rho_o \sigma}\ \frac{60}{88^2}\right)^{\frac{1}{2}} \left\{\frac{t \pm (t^2 - 4C_{D_o} Kw^2)^{\frac{1}{2}}}{2C_{D_o}}\right\}^{\frac{1}{2}}$$

Take $+ve$ root for maximum speed.

$$V = (14/\sqrt{\sigma})\frac{\{t + (t^2 - 4C_{D_o} Kw^2)^{\frac{1}{2}}\}^{\frac{1}{2}}}{C_{D_o}} \text{ m.p.h.}$$
$$\text{or } V = 12.2/\sqrt{\sigma}\sqrt{\quad\quad\quad\quad} \text{ knots.} \qquad . \quad . \quad (1)$$

2. MAXIMUM RATE OF CLIMB.

At a speed v, power available for climb $= Tv - Dv = Wv_c/60$

$$\frac{Wv_c}{60} = Tv - \tfrac{1}{2}\rho v^3 S(C_{D_o} + KC_L^2)$$

But $v^2 = 2W/\rho C_L S$

$$\therefore Wv_c/60 = T\left(\frac{2W}{\rho S}\right)^{\frac{1}{2}} C_L^{-\frac{1}{2}} - \left(\frac{\rho S C_{D_o}}{2}\right)\left(\frac{2W}{\rho S}\right)^{3/2} C_L^{-3/2} - \left(\frac{\rho SK}{2}\right)\left(\frac{2W}{\rho S}\right)^{3/2} C_L^{\frac{1}{2}}$$

For a maximum: $\frac{d(Wv_c)}{dC_L} = 0$

$$\therefore \quad 0 = -\left(\frac{T}{2}\right)\left(\frac{2W}{\rho S}\right)^{\frac{1}{2}} C_L^{-3/2} + \left(\frac{3}{2}\right)\left(\frac{\rho S C_{D_o}}{2}\right)\left(\frac{2W}{\rho S}\right)^{-3/2} C_L^{-5/2} - \tfrac{1}{2}\left(\frac{\rho SK}{2}\right)\left(\frac{2W}{\rho S}\right)^{3/2} C_L^{-\frac{1}{2}}$$
$$\text{or } 0 = -\left(\frac{T}{2}\right)C_L^{-3/2} + \frac{3}{2} WC_{D_o} C_L^{-5/2} - \tfrac{1}{2} KWC_L^{-\frac{1}{2}}$$
$$= -\left(\frac{T}{W}\right)C_L + 3C_{D_o} - KC_L^2$$
$$= KC_L^2 + \left(\frac{T}{W}\right)C_L - 3C_{D_o}$$

Then $C_{L_c} = T/W + \{(T/W)^2 + 12KC_{D_o}\}^{\frac{1}{2}}/2K \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2a)$

As above: $Wv_c/60 = T\left(\frac{2W}{\rho S}\right)^{\frac{1}{2}} C_L^{-\frac{1}{2}} - \left(\frac{\rho S C_{D_o}}{2}\right)\left(\frac{2W}{\rho S}\right)^{3/2} C_L^{-3/2} - \left(\frac{\rho SK}{2}\right)\left(\frac{2W}{\rho S}\right)^{3/2} C_L^{\frac{1}{2}}$

$$\text{or } v_c = \left(\frac{2W}{\rho S}\right)^{\frac{1}{2}} C_L^{-\frac{1}{2}} \left\{ \frac{T}{W} - \frac{C_{D_o}}{C_L} - KC_L \right\} \times 60$$

$$= (2w/\rho_o\sigma)^{\frac{1}{2}} (60/C_L^{\frac{1}{2}}) \left\{ \frac{T}{W} - \frac{C_{D_o}}{C_L} - KC_L \right\} \text{ ft./min.}$$

$$v_{c\max} = \frac{1750}{\sqrt{\frac{\sigma}{w}}\sqrt{C_{L_c}}} \left\{ \frac{T}{W} - \frac{C_{D_o}}{C_{L_c}} - KC_{L_c} \right\} \text{ ft./min.} \quad . \quad . \quad . \quad (2b)$$

where C_{L_c} is found from (2a) above.

Forward speed for maximum rate of climb

$$v^2 = \frac{2W}{\rho_o\sigma C_{L_c} S} \text{ or } V_c = \frac{19.8}{\sqrt{C_{L_c}}\sqrt{\frac{\sigma}{w}}} \text{ m.p.h.} = \frac{17.2}{\sqrt{C_{L_c}}\sqrt{\frac{\sigma}{w}}} \text{ knots} \quad . \quad . \quad (2c)$$

3. ABSOLUTE CEILING.

This is reached when the available thrust (assumed constant with speed) becomes reduced to a value just equal to the minimum drag.

$$D = \tfrac{1}{2}\rho_o\sigma v^2 S (C_{D_o} + KC_L^2)$$

$$\text{and } v^2 = \frac{2W}{\rho_o\sigma C_L S}$$

$$\text{then } D = \frac{W}{C_L}(C_{D_o} + KC_L^2) = WC_{D_o}C_L^{-1} + WKC_L$$

$$\frac{dD}{dC_L} = -WC_{D_o}C_L^{-2} + WK = 0 \text{ for minimum.}$$

$$\therefore C_L^2 = C_{D_o}/K \text{ and } D_{\min} = \{ W/(C_{D_o}/K)^{\frac{1}{2}} \} (C_{D_o} + C_{D_o})$$

$$D_{\min} = T = 2W\sqrt{C_{D_o}K} \text{ at absolute ceiling.}$$

In the stratosphere, above 36,090 feet $T \propto \sigma$(relative density), then at the absolute ceiling

$$H_o, \text{ thrust } T = T_{36}, \times \left(\frac{\sigma H_o}{\sigma_{36}}\right)$$

$$\text{or } \sigma H_o = 0.594\,(W/T_{36})(C_{D_o}K)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (3)$$

where T_{36} is the total thrust at 36,090 feet.

4. RANGE.

It is assumed that as the engine r.p.m., and consequently the thrust and aircraft forward speed, are reduced, the specific consumption, lb. of fuel/lb. of thrust/hour, remains constant over the range from "all-out level" down to "most economical."

$$\text{M.p.g.} = \frac{\text{M.p.h.}}{\text{Gals./hr.}} = \frac{\text{Speed}}{\text{Thrust} \times \text{Spec. consumption}} \times \text{lb./gal.}$$

$\therefore$ Maximum range attained when $\frac{\text{thrust}}{\text{speed}}$ is a minimum

$$\frac{T}{v} = \frac{D}{v} = \{ \tfrac{1}{2}\rho S v^2 (C_{D_o} + KC_L^2) \}\, v$$

$$\text{But } v^2 = \frac{2W}{\rho SC_L} \quad \therefore \frac{T}{v} = \tfrac{1}{2}\rho\,(2W/\rho SC_L)^{\frac{1}{2}} S (C_{D_o} + KC_L^2)$$

$$\frac{T}{v} = \tfrac{1}{2}\rho S (2W/\rho S)^{\frac{1}{2}} (C_{D_o}C_L^{-\frac{1}{2}} + KC_L^{3/2})$$

For a minimum $d(T/v)/dC_L = 0$

$$0 = -\tfrac{1}{2}C_{D_0}C_L^{-3/2} + {}^{3}/_{2}KC_L^{\frac{1}{2}}$$

$$C_{D_0} = 3KC_L^2 \quad i.e. \quad C_{D_i} = \tfrac{1}{3}C_{D_0}$$

Then $v^2 = 2W/\{\rho S(C_{D_0}/3K)^{\frac{1}{2}}\}$

$$V_{econ} = (60/88)(2\sqrt{3}/\rho_0)^{\frac{1}{2}}\{1/(\sigma/w)^{\frac{1}{2}}\}(K/C_{D_0})^{\frac{1}{4}}$$

$$V_{econ} = \{26.1/(\sigma/w)^{\frac{1}{2}}\}(K/C_{D_0})^{\frac{1}{4}} \text{M.p.h.} = \{22.7/(\sigma/w)^{\frac{1}{2}}\}(K/C_D)^{\frac{1}{4}} \text{ knots} \quad . \quad (4)$$

The thrust at this speed is given by

$$T_{econ} = \tfrac{1}{2}\rho S v^2_{econ}(C_{D_0} + KC_L^2)$$

$$= \tfrac{1}{2}\rho S(2W/\rho S)(3K/C_{D_0})^{\frac{1}{2}}(C_{D_0} + KC_{D_0}/3K)$$

on substituting for v_{econ} and C_L from above,

Then

$$T_{econ} = W\frac{4\sqrt{3}}{3}\sqrt{C_{D_0}K} = T_{econ} = 2.31W\sqrt{C_{D_0}K} \quad . \quad . \quad . \quad (5)$$

Having thus found V_{econ} and T_{econ} the corresponding r.p.m. may be found from the engine performance curves, and hence the consumption in gallons/hour.

$$\text{Then miles/gallon} = \frac{\text{Miles per hour}}{\text{Gallons/hour}}$$

DURATION.

For constant specific consumption, maximum duration will be obtained for the speed of minimum drag, *i.e.*, when

$$\frac{D}{L} = 2\sqrt{C_{D_0}K} = \frac{T}{W} \text{ or } T = 2W\sqrt{C_D K} \quad . \quad . \quad . \quad . \quad (6)$$

The corresponding speed $V \quad \{19.8/(\sigma/w)^{\frac{1}{2}}\}(K/C_{D_0})^{\frac{1}{4}}$ m.p.h.

$$= \{17.2/(\sigma/w)^{\frac{1}{2}}\}(K/C_{D_0})^{\frac{1}{4}} \text{ knots.} \quad . \quad . \quad . \quad . \quad (7)$$

SUMMARY.

1. MAXIMUM LEVEL SPEED (NO COMPRESSIBILITY).

$$V = (14/\sigma^{\frac{1}{2}})[\{t + (t^2 - 4C_{D_0}Kw^2)^{\frac{1}{2}}\}/C_{D_0}]^{\frac{1}{2}} \text{ m.p.h.}$$

$$\text{or } (12.2/\sigma^{\frac{1}{2}})[\{t + (t^2 - 4C_{D_0}Kw^2)^{\frac{1}{2}}\}/C_{D_0}]^{\frac{1}{2}} \text{ knots} \quad . \quad . \quad . \quad (1)$$

$$[t = T/S,\ K = C_{D_i}/C_L^2]$$

2. MAXIMUM RATE OF CLIMB.

$$C_{L_c} = -T/W + \{(T/W)^2 + 12KC_{D_0}\}^{\frac{1}{2}}/2K \quad . \quad . \quad . \quad (2a)$$

$$v_{c_{max}} = \frac{1750}{\sqrt{(\sigma/w)}\sqrt{(C_{L_c})}}\{T/W - C_{D_0}/C_{L_c} - KC_{L_c}\} \text{ ft./minute} \quad . \quad . \quad (2b)$$

FORWARD SPEED.

$$V_{cl} = \frac{19.8}{\sqrt{(C_{L_c})}\sqrt{(\sigma/w)}} \text{ m.p.h.} = \frac{17.2}{\sqrt{(C_{L_c})}\sqrt{(\sigma/w)}} \text{ knots} \quad . \quad . \quad (2c)$$

3. ABSOLUTE CEILING.

$$\sigma_{H_0} = 0.594(W/T_{36})\sqrt{(C_{D_0}K)} \quad T_{36} = \text{Total thrust at 36,000 ft.} \quad . \quad . \quad (3)$$

4. RANGE.

$$\left.\begin{aligned} V_{\text{econ}} &= \{\, 26.1/\sqrt{(\sigma/w)}\,\}\,(K/C_{D_o})^{\frac{1}{4}} \text{ m.p.h.} \\ &= \{\, 22.7/\sqrt{(\sigma/w)}\,\}\,(K/C_{D_o})^{\frac{1}{4}} \text{ knots} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Gals./hr. consumption = (specific consumption × thrust) × lb./gal.

$$T_{\text{econ}} = 2.31W\,(C_{D_o}K)^{\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$\text{Best m.p.g.} = \frac{V_{\text{econ}}\ \text{(m.p.h.)}}{\text{gals./hr.}}$$

5. DURATION.

$$T = 2W\,(C_{D_o}K)^{\frac{1}{4}} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$\left.\begin{aligned} V &= \{\, 19.8/(\sigma/w)^{\frac{1}{4}}\,\}\,(K/C_{D_o})^{\frac{1}{4}} \text{ m.p.h.} \\ &= \{\, 17.2/(\sigma/w)^{\frac{1}{4}}\,\}\,(K/C_{D_o})^{\frac{1}{4}} \text{ knots} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Appendix II.

SPEED WITH COMPRESSIBILITY.

The effect of compressibility on drag is to cause a fairly sudden rise in the drag coefficient at a value of the Mach number determined mainly by the thickness/chord ratio of the wing. One result of this is that any analytical method of estimating maximum level speed breaks down and recourse must be had to a graphical method, such as the following:—

1. The first requirement is a set of curves of C_D at constant C_L for the complete aircraft as a function of Mach number (Fig. 1).

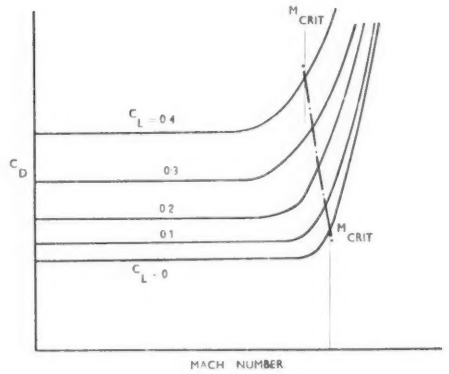


Fig. 1.
Drag curves (constant C_L).
M_{CRIT} = drag critical Mach number when C_D = 1.25 × low speed value.

These are usually obtained from high-speed tunnel tests, but, failing this, estimated curves may be drawn if generalised curves are available for (*i*) M_{cr} at the aerofoil design C_L, as a function of thickness/chord ratio and (*ii*) variations of M_{cr} with C_L (dependent mainly on position of maximum ordinate).

2. The next step is to draw a set of curves of C_L against Mach number for each height at which the speed is required (Fig. 2).

These are plotted from the relation

$$C_L = \frac{w}{\frac{1}{2}\rho v^2} = \frac{w}{\frac{1}{2}\rho\left(\frac{v}{a}\right)^2 a^2} = \frac{w}{\frac{1}{2}\rho a^2}\,\frac{1}{M^2}$$

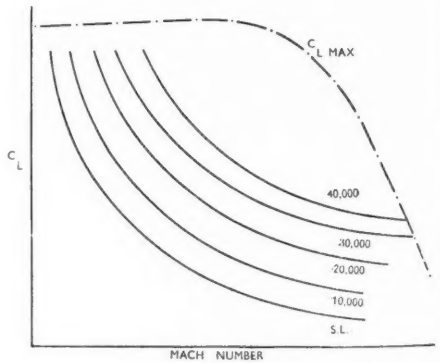


Fig. 2.
C_L curves.

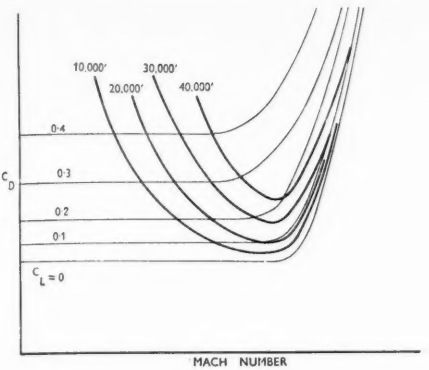


Fig. 3.
Drag curves (constant height).

where ρ, a are respectively the density and speed of sound at the particular height in question. Another effect of compressibility is a reduction in C_L max at high Mach numbers, about the same as that at which there is the rise of C_D, and if the aircraft is to fly at very great heights or has an exceptionally heavy wing loading it may be necessary to check that the C_L max is not exceeded; the curve of C_L max against M may be obtained from the "lift carpet" of the H.S.T. tests.

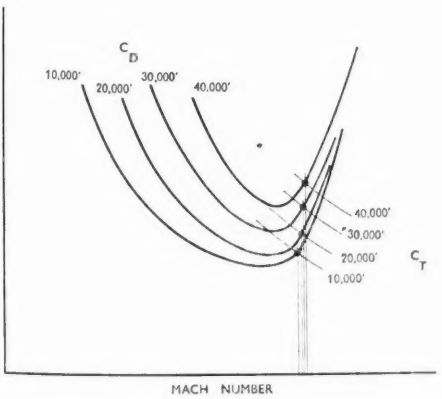


Fig. 4.
Drag and thrust curves.

3. On the drag curves of Fig. 1 may now be marked, for each constant value of C_L, the appropriate value of M, obtained from Fig. 2. The locus of these points will now be a curve of C_D against M for each height considered (Fig. 3).

(The difference between these curves and the first set is that they are for constant lift (=weight) and not constant lift *coefficient*.)

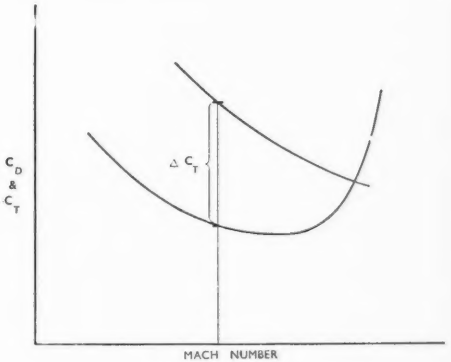


Fig. 5.
Climb with compressibility.

It will now be most convenient to transfer these last curves to an overlay sheet, for the final step is to plot on this a series of curves of available thrust, in the form of thrust coefficient = thrust/$(\frac{1}{2}\rho Sv^2) = C_T$ (Fig. 4). This will usually involve less labour than the alternative method of converting the C_D curves to drag or power required. The intersection of the C_D and C_T curves for each height then gives the Mach number and hence the speed of maximum level flight at that height.

The method is of course applicable to any method of propulsion; propeller, ducted fan jet or rocket, so long as a curve of thrust versus speed is available.

CLIMB WITH COMPRESSIBILITY.

For jet-propelled aircraft with high thrust/weight ratios it may be found that even at climbing speeds the critical Mach number is reached; when this is so Fig. 4 (with the

necessary extension of the engine C_T curves) may be used to find the maximum rate of climb, Fig. 5.

$$\Delta_T = \Delta C_T \rho S v^2 \qquad \Delta T.H.P. = \frac{\Delta C_T \rho S v^3}{550}$$

$$v_c = \frac{\Delta T.H.P. 550}{W} \text{ ft./sec.} \qquad \frac{\Delta C_T \rho S v^3}{W} = \Delta C_T v^3 \sigma \frac{\rho_0}{w}$$

$$v_c \text{ ft./min.} = \Delta C_T M^3 \sigma a^3 \left(\frac{88}{60}\right)^3 \times \frac{0.00238}{w} \times 60$$

$$= \Delta C_T M^3 \sigma a^3 \times \frac{0.455}{w} \quad (a = \text{speed of sound, m.p.h.})$$

v_c may then be plotted against M and the maximum value found by inspection.

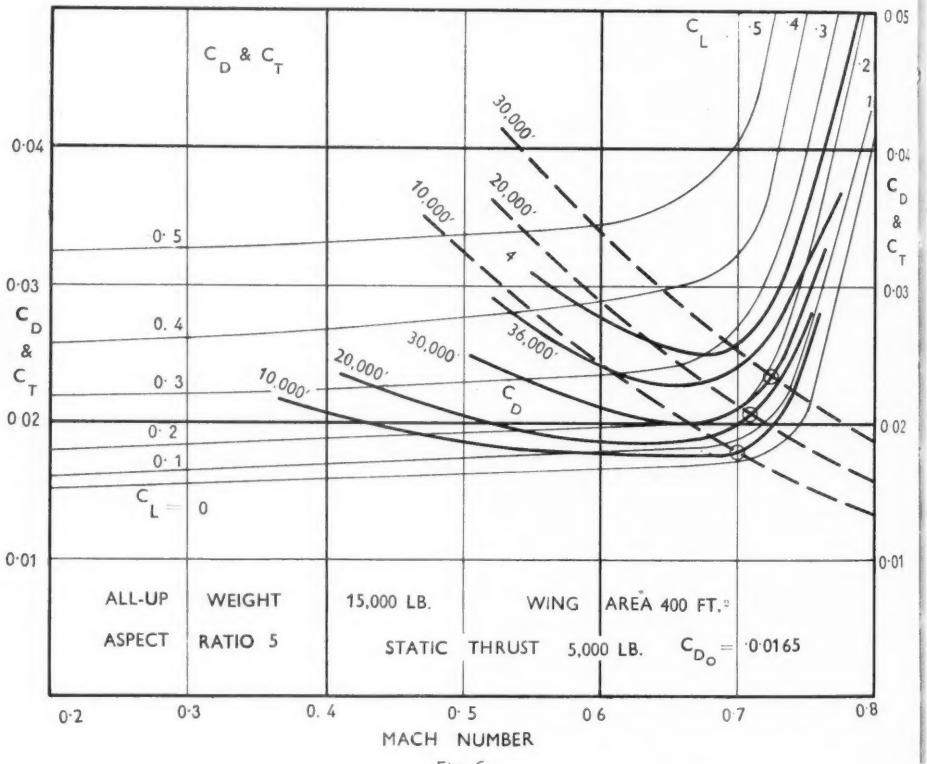


Fig. 6.
Performance of typical jet-propelled aircraft—drag and thrust.

Appendix III.

TYPICAL EXAMPLE.

The curves 6, 7, 8 and 9 show the results of some typical calculations done by the methods described previously and should serve to give an idea of the general shape and form of the final curves.

Figure 6 shows curves of C_L against Mach number, cross-plotted on the family of curves

ALL-UP WEIGHT 15,000 LB. WING AREA 400 FT.²

ASPECT RATIO 5 STATIC THRUST 5,000 LB. $C_{D_o} = 0.0165$

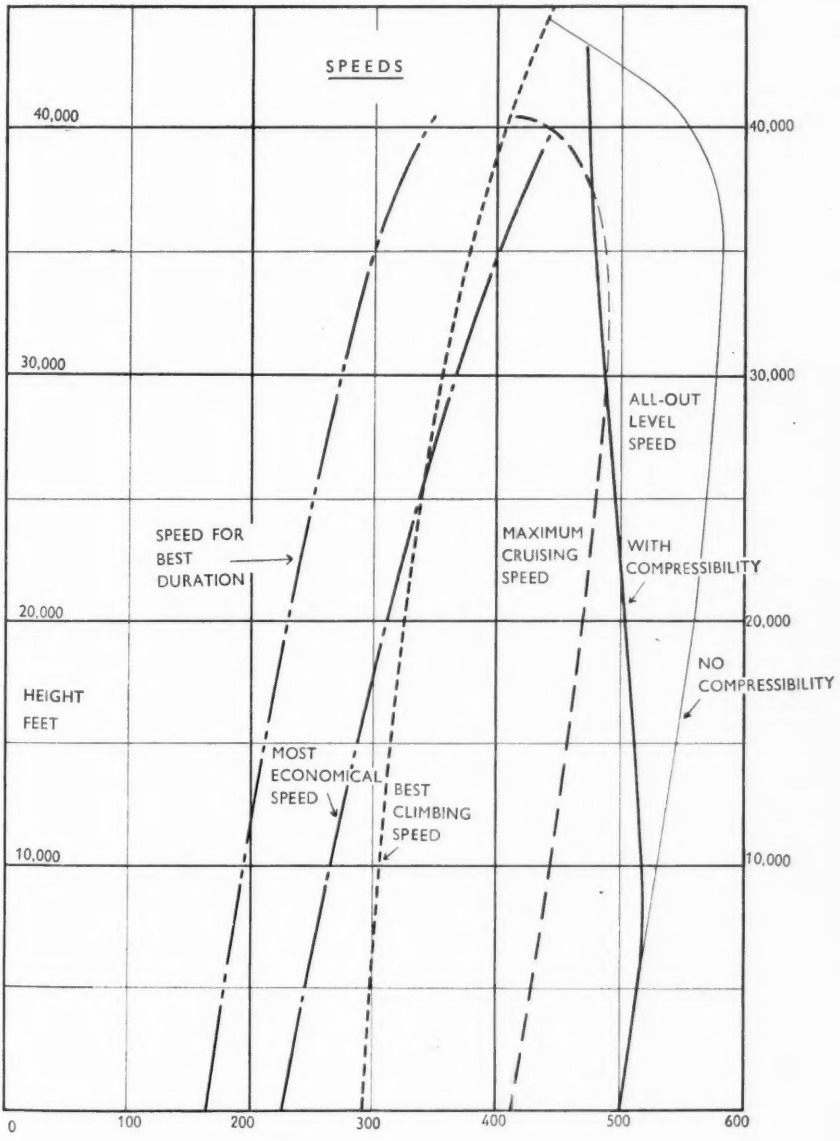


Fig. 7.
Performance of typical jet-propelled aircraft—speeds.

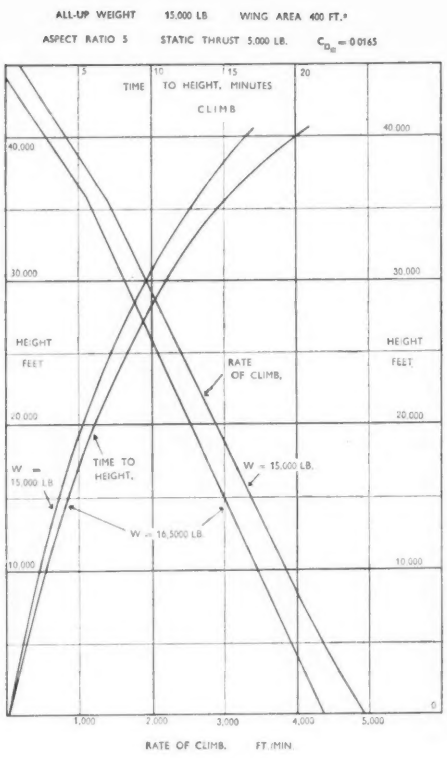

ALL-UP WEIGHT 15,000 LB. WING AREA 400 FT.²
ASPECT RATIO 5 STATIC THRUST 5,000 LB. $C_{D_0} = 0.0165$
TIME TO HEIGHT, MINUTES CLIMB
HEIGHT FEET
RATE OF CLIMB,
TIME TO HEIGHT,
W = 15,000 LB.
W = 15,500 LB.
W = 16,500 LB.
RATE OF CLIMB, FT./MIN.

Fig. 8.
Performance of typical jet-propelled aircraft—climb.

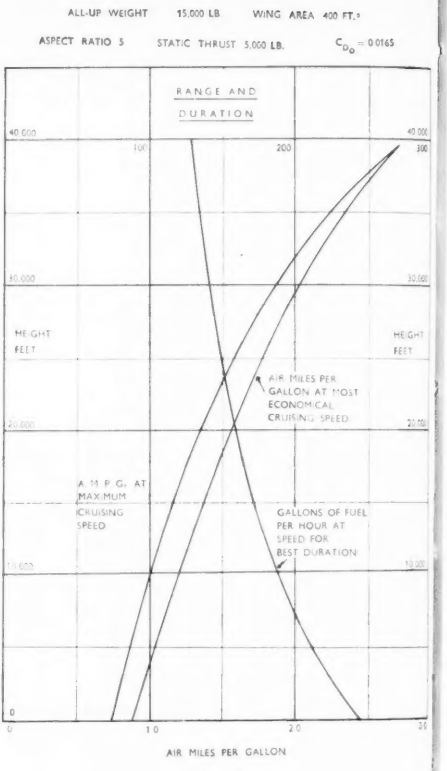

ALL-UP WEIGHT 15,000 LB. WING AREA 400 FT.²
ASPECT RATIO 5 STATIC THRUST 5,000 LB. $C_{D_0} = 0.0165$
RANGE AND DURATION
HEIGHT FEET
AIR MILES PER GALLON AT MOST ECONOMICAL CRUISING SPEED
A.M.P.G. AT MAXIMUM CRUISING SPEED
GALLONS OF FUEL PER HOUR AT SPEED FOR BEST DURATION
AIR MILES PER GALLON

Fig. 9.
Performance of typical jet-propelled aircraft—fuel consumption.

of C_D against Mach number for varying values of C_L. Also shown are curves of $C_T = \text{Thrust}/(\frac{1}{2}\rho S v^2)$ for three heights. The intersections of these with the appropriate C_D curves show the Mach numbers attained at those heights; this enables the curve of top speeds with the effects of compressibility to be drawn on a Fig. 7. Here it will be seen that near the ceiling the maximum cruising speed also approaches the compressibility region in this instance. Fig. 8 shows typical climb curves; here, with a fairly low thrust weight ratio of 0.33, the rates of climb are not exceptionally high and the climbing speeds are not affected by compressibility. Fig. 9 shows fuel consumptions, from which for a given fuel load, the ranges and durations could be found for various operating heights.

I am indebted to Westland Aircraft Limited for permission to publish this work, but any opinions expressed therein are entirely my own.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

EIGHTY-SECOND ANNUAL REPORT OF THE COUNCIL 1946-1947

THE year 1946, the first complete year of peace, has seen a considerable increase in the activities of the Society.

During the year the Committees of Council were re-organised on a basis which enabled the increasing work of the Society to be more actively pushed forward and co-ordinated. Each of the three Vice-Presidents has become responsible for certain aspects of the Society's work.

Sir Oliver Simmonds has been in charge of the General Purposes Committee, and through that Committee for the revision of the Rules of the Society, and all the many problems affecting membership and the Society's general policy.

Dr. H. Roxbee Cox, as Chairman of the Technical Committee, has been responsible for the rapidly increasing technical work of the Society. Through the Technical Committee the following Sub-Committees report: Structures, Aerodynamics, Engines, Materials, Detail Design, Fuels and Oil, and Aircraft Instruments and Equipment.

Mr. N. E. Rowe, Chairman of the Branches Committee, is responsible for the co-ordination of the activities of the Branches of the Society. Under his Chairmanship every effort is being made to keep the Branches in closer touch with headquarters and with one another.

During the year the Rules Sub-Committee, under the Chairmanship of Sir Oliver Simmonds, revised and simplified the Rules of the Society. The main objects of the simplification were to raise the qualifications and status of certain grades, and to put the rules in such a form that they would facilitate the application for a Charter which the Council have in view.

The Council wish to place on record the greatly increased attendances at the lectures which have been held during the year. It is a matter of regret that the Society has no lecture hall of its own. A Lecture Hall Sub-Committee has been exploring the possibilities of a Lecture Hall for some time, despite the difficulties of the present situation, so that no considerations are overlooked.

COUNCIL—1946-47

PRESIDENT

SIR FREDERICK HANDLEY PAGE, C.B.E., F.R.Ae.S.

PAST PRESIDENTS

SIR A. H. ROY FEDDEN, M.B.E., D.Sc., M.I.Mech.E., M.I.A.E., M.S.A.E., F.R.Ae.S.
MR. A. GOUGE, B.Sc., F.R.Ae.S.
MR. GRIFFITH BREWER, Hon. F.R.Ae.S.

VICE-PRESIDENTS

DR. H. ROXBEE COX, Ph.D., D.I.C., B.Sc., F.I.Ae.S. F.R.Ae.S.
SIR OLIVER SIMMONDS, M.A., F.R.Ae.S.
Mr. N. E. ROWE, C.B.E., B.Sc., D.I.C., F.R.Ae S.

Mr. E. J. N. ARCHBOLD, B.Sc., Grad.R.Ae.S.
Air Commodore F. R. BANKS, C.B., O.B.E., M.I.A.E., F.I.P., M.S.A.E., M.I.Mech.E., F.R.Ae.S.
Lord BRABAZON OF TARA, M.C., F.R.Ae.S.
Sir JOHN S. BUCHANAN, C.B.E., A.M.I.Mech.E., F.R.Ae.S.
Major G. P. BULMAN, C.B.E., B.Sc., F.R.Ae.S.
Mr. S. CAMM, C.B.E., F.R.Ae.S.
Mr. G. P. DOUGLAS, O.B.E., M.C., D.Sc., F.R.Ae.S.
Mr. A. G. ELLIOTT, C.B.E., M.I.A.E., M.S.A.E., F.R.Ae.S.
Mr. W. S. FARREN, C.B., M.B.E., F.R.S., M.A., M.I.Mech.E., F.R.Ae.S.
Mr. E. T. JONES, O.B.E., M.Eng., F.R.Ae.S.
Sir BEN LOCKSPEISER, M.A., F.C.S., F.R.Ae.S.
Mr. P. G. MASEFIELD, M.A., F.R.Ae.S.
Major R. H. MAYO, O.B.E., M.A., A.M.Inst.C.E., F.R.Ae.S.
Mr. W. G. A. PERRING, F.R.Ae.S.
Captain C. F. UWINS, A.F.C., O.B.E., F.R.Ae.S.
Mr. B. N. WALLIS, C.B.E., F.R.S., B.Sc., R.D.I., M.Inst.C.E., F.R.Ae.S.

Honorary Librarian: Mr. J. E. HODGSON, Hon.F.R.Ae.S.

Solicitor: Mr. L. A. WINGFIELD, M.C., D.F.C., A.R.Ae.S.

Honorary Treasurer: Capt. C. F. UWINS, A.F.C., O.B.E., F.R.Ae.S.

Secretary: Capt. J. LAURENCE PRITCHARD, F.I.Ae.S., Hon.F.R.Ae.S.

NOTE—The President and Vice-Presidents are elected in May or June and take office in October of each year.

COMMITTEES

Aerodynamics Sub-Committee
Mr. H. B. IRVING (*Chairman*)
Mr. R. M. CLARKSON
Mr. D. KEITH-LUCAS
Mr. G. H. LEE
Mr. H. F. VESSEY
Mr. A. D. YOUNG

Branches Committee
Mr. N. E. ROWE (*Chairman*)
Mr. E. J. N. ARCHBOLD
Mr. J. L. BATCHELOR
W/Cdr. T. R. CAVE-BROWN-CAVE
Mr. W. S. FARREN
Mr. H. GIDDINGS
Mr. C. P. HOMES
Mr. P. G. MASEFIELD
Major B. W. SHILSON
Dr. H. C. WATTS
Mr. F. A. WILKINSON

Education and Examinations Committee
Mr. W. S. FARREN (*Chairman*)
Mr. W. H. COOPER
Dr. G. P. DOUGLAS
Mr. W. E. DUMBRILL
Professor F. T. HILL
Professor G. T. R. HILL
Mr. M. LANGLEY
Dr. N. A. V. PIERCY
Air Commodore A. H. ROBSON

Engines Sub-Committee
Captain M. LUBY (*Chairman*)
Mr. R. N. DOREY
Mr. E. S. MOULT

Finance Committee
Captain C. F. UWINS (*Chairman*)
Sir JOHN S. BUCHANAN
Major G. P. BULMAN
Col. W. C. DEVEREUX
Sir BEN LOCKSPEISER
Capt. A. G. LAMPLUGH
Major R. H. MAYO

General Purposes Committee
Sir OLIVER SIMMONDS (*Chairman*)
Lord BRABAZON
Sir JOHN S. BUCHANAN
Mr. W. S. FARREN
Sir ROY FEDDEN
Mr. A. GOUGE
Mr. P. G. MASEFIELD
Major R. H. MAYO
Captain C. F. UWINS

Grading Committee
Dr. H. C. WATTS (*Chairman*)
Sir JOHN S. BUCHANAN
Major G. P. BULMAN
Mr. A. C. CLINTON
Professor F. T. HILL
Mr. R. S. STAFFORD

Journal Committee
Mr. G. H. DOWTY (*Chairman*)
Air Commodore F. R. BANKS
Wing Commander C. G. BURGE
Mr. F. H. M. LLOYD
Major R. H. MAYO
Mr. P. G. MASEFIELD
Professor A. G. PUGSLEY

Lectures and Debates Committee
Major G. P. BULMAN (*Chairman*)
Mr. E. T. JONES
Sir BEN LOCKSPEISER
Mr. W. G. A. PERRING
Mr. J. G. ROXBURGH
Major C. J. STEWART
Mr. B. N. WALLIS

Materials Sub-Committee
Professor L. AITCHISON (*Chairman*)
Dr. B. CHALMERS
Mr. H. H. GARDNER
Mr. H. GRINSTED

Medals and Awards
Mr. A. GOUGE (*Chairman*)
Mr. W. S. FARREN
Sir ROY FEDDEN
Professor G. T. R. HILL
Mr. W. G. A. PERRING
Professor A. G. PUGSLEY
Major C. J. STEWART

Performance Panel
Mr. H. DAVIES (*Chairman*)
Mr. W. J. ANNAND
Mr. S. R. HUGHES
Mr. D. R. NEWMAN
Mr. R. WHITBY

Rules Sub-Committee
Sir OLIVER SIMMONDS (*Chairman*)
Mr. A. C. CLINTON
Major R. H. MAYO
Dr. H. ROXBEE COX
Mr. W. TYE
Dr. H. C. WATTS
Mr. L. A. WINGFIELD

Structures Sub-Committee
Mr. H. L. COX (*Chairman*)
Mr. A. C. BROWN
Mr. H. GOODINGE
Mr. H. B. HOWARD
Mr. F. H. POLLICUTT
Professor A. G. PUGSLEY
Dr. S. C. REDSHAW
Dr. P. B. WALKER

Technical Committee

Dr. H. ROXBEE COX (*Chairman*)
Professor L. AITCHISON
Mr. H. L. COX
Mr. A. G. ELLIOTT
Sir ROY FEDDEN
Mr. H. M. GARNER
Mr. A. GOUGE
Mr. H. B. IRVING
Captain M. LUBY
Mr. R. K. PIERSON
Mr. N. E. ROWE
Mr. R. S. STAFFORD

REPRESENTATIVES ON OTHER BODIES

Advisory Committee for Aeronautical Engineering of the City and Guilds of London Institute: Professor F. T. Hill and Captain J. L. Pritchard.

Association of Special Libraries and Information Bureaux: Mr. J. E. Hodgson (Hon. Librarian).

British Standards Institution Aircraft Committee: Sir Roy Fedden and Mr. A. Gouge.

British Standards Institution Jewels and Bearings Committee: Major Shilson.

Engineering Joint Council: Sir Frederick Handley Page and Sir Oliver Simmonds.

Engineering Joint Council—Special Education Representative: Professor G. T. R. Hill.

National Central Library: Mr. J. E. Hodgson (Hon. Librarian).

Institution of Mechanical Engineers, National Certificates and Diplomas in Mechanical Engineering: Sir Frederick Handley Page and Professor F. T. Hill.

General Board of National Physical Laboratory: Mr. W. C. Devereux and Mr. A. Gouge.

College of Aeronautics: Sir Roy Fedden and Dr. H. Roxbee Cox.

British Gliding Association: Mr. G. H. Lee.

Segrave Trophy Committee: Major R. H. Mayo.

MEMBERSHIP

The membership of the Society continues to increase steadily, showing an addition of 754 subscribing members in comparison with the figure of 680 for 1945-46. The Council consider that this steady increase in the membership of the Society is most satisfactory. The increase following the 1939-45 War is all the more gratifying when it is compared with the heavy drop in membership following the 1914-18 War.

	Paid Members		Life and Hon. Members		Suspended		Totals	
Fellows	313	(292)	33	(34)	2	(1)	348	(327)
Associate Fellows	1741	(1517)	11	(9)	33	(41)	1785	(1567)
Associates	1831	(1551)	5	(5)	130	(54)	1966	(1610)
Graduates	643	(568)	—	(—)	14	(36)	657	(604)
Students	1176	(1136)	—	(—)	120	(101)	1296	(1237)
Founder Members	13	(16)	1	(1)	3	(1)	17	(18)
Companions	317	(200)	8	(7)	10	(9)	335	(216)
Temp. Hon. Members ...	—	(—)	30	(35)	—	(—)	30	(35)
Dec. 31st 1946	6034	(5280)	88	(91)	312	(243)	6434	(5614)

NOTE.—Figures in brackets give the membership at December 1945.

ANNUAL GENERAL MEETING

The Annual General Meeting of the Royal Aeronautical Society was held in the offices of the Society on Saturday 30th March 1946 at 2.45 p.m.

Present: Sir Frederick Handley Page (President) in the Chair.

E. J. N. Archbold (Graduate)
J. Bell (Associate)
Griffith Brewer (Honorary Fellow and Past President)
Major G. P. Bulman (Fellow)
Capt. J. H. Cordes (Associate Fellow)
G/Capt. W. N. Cumming (Associate Fellow)
Lt.-Col. A. E. Eadon (Fellow)
P. F. N. Edwards (Student)

C. R. Elgie (Associate)
G. Fitzgerald-Lee (Associate)
F. G. C. Henworth (Associate)
C. D. Holland (Associate Fellow)
Dr. D. M. A. Leggett (Associate Fellow)
Sir Francis McClean (Fellow)
R. K. Pierson (Fellow)
G. J. Richards (Associate Fellow)
Major B. W. Shilson (Fellow)
Sir Oliver Simmonds (Fellow)
D. C. Smith (Associate Fellow)
Whitney Straight (Associate)
R. T. Wall (Graduate)
J. A. C. Williams (Associate Fellow)
L. A. Wingfield (Associate)

In attendance: The Secretary and Miss Barwood.

1. The Secretary read the Notice convening the meeting.

2. The attention of members present was drawn to the Annual Report.

Mr. J. A. C. Williams (Associate Fellow) asked if any action had been taken with regard to a Benevolent Fund for Members. He had raised the question some years ago at an Annual Meeting and it was then agreed the matter should be explored.

The President said that the main object of the Society was the advancement of aeronautical science and engineering; while it was desirable no doubt to have a Benevolent Fund he did not think it came within the province of the Royal Aeronautical Society.

Mr. Williams replied that the Institution of Mechanical Engineers had their own benevolent fund for their members, and he thought the Society should have such a scheme for its members.

The President agreed it would be a good thing to raise some money, but the Society of British Aircraft Constructors and the Royal Aero Club might be consulted and make it an omnibus Benevolent Fund. The main point would be to launch an appeal at the appropriate time.

Mr. Williams then enquired if it would be in order that the Council be asked to consider such a scheme, and the President agreed they might take the matter up with the other bodies.

The adoption of the Report was then moved by Sir Francis McClean, seconded by Mr. L. A. Wingfield, and carried.

3. As a result of the Ballot the Secretary reported the following nominations to fill the 10 vacancies on the Council:—

Mr. E. J. N. Archbold
Air Commodore F. R. Banks
Lord Brabazon of Tara
Sir John Buchanan
Dr. G. P. Douglas
Mr. A. G. Elliott
Mr. E. T. Jones
Sir Ben Lockspeiser
Mr. W. G. A. Perring
Mr. N. E. Rowe

4. The Secretary read the names of those proposed for Fellowship and passed by the Council, as follows:—

Dr. L. Aitchison
A. A. Bage
A. G. Berg
W. Browning
H. G. Conway
C. Cornwall
C. L. Cowdrey
G. E. Edwards
F. G. Evans
W. Garrow-Fisher
Professor S. Goldstein
W. H. Hambrook

W. A. Hargreaves
Professor A. A. Hall
P. V. Hoare
C. D. Holland
J. P. Jeffcock
J. Johnston
A. C. Lovesey
D. F. Lucking
J. A. C. Manson
E. T. B. Marples
C. E. R. Osman
T. P. de Paravicini
D. G. Samaras
Admiral M. S. Slattery
P. W. Smith
W. F. Spurr
J. C. Stevenson
H. J. Swift
W. M. Widgery
E. W. C. Wilkins
H. Wood
H. M. Woodhams

5. Sir Francis McClean proposed that Messrs. Price Waterhouse be re-elected Auditors for the ensuing year for Aerial Science Limited and Aeronautical Trusts Limited. Mr. Wingfield seconded the proposal, which was passed unanimously.

6. The meeting finished at 3 p.m.

DONATIONS

The Council, for the 22nd year in succession, have to thank the Society of British Aircraft Constructors for their grant of £250 to the Funds of the Society.

The Endowment Fund in 1945 reached a total of £131,775 15s. 9d., and this year stands at £133,719 13s. 8d.

The growth of the Fund since 1939 was mainly due to the generous gifts, spread over seven years, from many individuals and firms in the industry. These gifts have now all been received.

The Council are anxious that a considerably greater sum should be raised. They hope that all members will bear the Fund in mind and add to it.

PRESIDENT

Sir Frederick Handley Page, C.B.E., F.R.Ae.S., was elected President of the Society for a further term of office for the year October 1946—September 1947.

VICE-PRESIDENTS

The following were elected Vice-Presidents of the Society for the year 1946-1947:—

Dr. H. Roxbee Cox, Ph.D., D.I.C., B.Sc., F.R.Ae.S.
Sir Oliver Simmonds, M.A., F.R.Ae.S.
Mr. N. E. Rowe, C.B.E., B.Sc., D.I.C., F.R.Ae.S.

MEDALS AND AWARDS

The following awards were made during the year:—

Elliott Memorial Prize—Aircraft Apprentice F. I. Langley, Corporal Apprentice P. Fairhurst.

Baden-Powell Memorial Prize—J. G. Mason, E. M. Dowlen.
(Awarded to the best student in the May and December Associate Fellowship Examination)

Busk Studentship—R. P. Boswell.

Usborne Prize—O. R. Ballard.

HONOURS

Members who received honours from H.M. The King during the year were as follows:

New Year Honours—January 1946:—

O.M.

The Right Honourable Winston L. S. Churchill, C.H., F.R.S., M.P., Honorary Fellow.

Knighthood.

Ben Lockspeiser, Fellow.

C.B. (Military Division).

Air Commodore F. R. Banks, O.B.E., R.A.F., Fellow.
Captain (Acting Rear-Admiral) M. S. Slattery, Assoc. Fellow.

C.B.E. (Military Division).

Act. Air Commodore J. F. Titmus, R.A.F., Assoc. Fellow.
Group Captain R. H. Horniman, R.A.F., Assoc. Fellow.

O.B.E. (Military Division).

G/C. N. C. Ogilvie-Forbes, R.A.F., Assoc.
W/C. A. J. Edmunds, R.A.F., Assoc.
W/C. A. K. Hunter, R.A.F., Assoc. Fellow.
Act. W/C. D. D. M. Butcher, R.A.F.O., Student.
Act. W/C. R. H. C. Brousson, R.A.F.V.R., Assoc.
Act. W/C. Keith Hitchins, R.A.F.V.R., Assoc.
Act. W.C. John Jewell, R.A.F., Assoc. Fellow.
Act. W/C. J. D. Sumner, R.A.F.V.R., Assoc. Fellow.
Act. W/C. Joseph Williams, R.A.F., Assoc. Fellow.
Act. W/C. S. T. Freeman, R.A.F.V.R., Assoc.

M.B.E. (Military Division).

S/L. J. G. Gunn, R.A.F.V.R., Assoc.
Act. S/L. S. F. Mitchell, R.A.F., Assoc. Fellow.
F/L. M. J. I. Kemper, R.A.F.V.R., Student.
F/L. R. J. MacCallum, R.A.F., Assoc.
Act. F/L. Richard Los, R.A.F., Assoc.
Act. F/L. Norman Scott, R.A.F.V.R., Student.
F/O. R. J. McAusland, R.A.F., Companion.
W/O. S. G. Smith, R.A.F., Assoc.

C.B.E. (Civil Division).

Joseph Smith, Fellow.
G. R. Volkert, Fellow.

O.B.E. (Civil Division).

R. H. Chaplin, B.Sc., Fellow.
C. L. Hinings, Assoc. Fellow.
A. C. Lovesey, Assoc. Fellow.
H. J. Penrose, Fellow.
J. B. Prior, Assoc. Fellow.
T. R. Thomas, Fellow.

M.B.E. (Civil Division).

S/L. L. S. Ash, R.A.F.V.R., Assoc. Fellow.
C. R. Burgess, Assoc.
H. E. Chaplin, Fellow.
W. A. Hargreaves, Fellow.
D. F. Horne, Assoc. Fellow.
Harold Rogerson, Fellow.
F. S. Saunders, Assoc Fellow.
W/C. R. C. Warren, Assoc.
H. M. Wilson, Ph.D., A.M.I.Mech.E., Assoc. Fellow.

The Birthday Honours List—June 1946:—

C.B.E. (Military Division).

Group Captain C. Rapley, R.A.F., Assoc. Fellow.
Group Captain H. J. Wilson, A.F.C., R.A.F., Assoc.

C.B.E. (Civil Division).

R. E. Bishop, Esq., Assoc.
Harold Grinsted, Esq., O.B.E., Fellow.
Captain A. G. Lamplugh, Fellow.

O.B.E. (Military Division).

W/C. E. L. T. Barton, R.A.F.V.R., Assoc. Fellow.
W/C. M. D. Day, R.A.F., Assoc.
L/C. (E.) C. C. Mitchell, R.N.V.R., Assoc. Fellow.
W/C. V. C. Otter, R.A.F., Assoc.

O.B.E. (Civil Division).

A. B. Barbour, Esq., M.R.C.S., L.R.C.P., Assoc. Fellow.
E. S. Greenwood, Esq., Assoc.
S. G. Hooker, Esq., D.Phil., Assoc. Fellow.
W/C. (Acting Air Commodore) the Hon. W. L. Runciman, A.F.C., Companion.
D. N. Walker, Esq., A.M.I.Mech.E., M.I.A.E., Assoc. Fellow.
G. O. Waters, Esq., Assoc.

M.B.E. (Military Division).

Mr. W. R. Booley, Temporary Acting Commissioned Aircraft Officer, R.N., Assoc.
Lieut. (A.) (A.E.) H. A. Jarrett, R.N., Assoc.
S/L. F. C. Wolley, R.A.F., Assoc.

M.B.E. (Civil Division).

B. Kaiser, Esq., A.M.I.Mech.E., M.I.Ae.S., Assoc. Fellow.
Sydney Oldfield, Esq., Assoc.

SOCIETY OF BRITISH AIRCRAFT CONSTRUCTORS' SCHOLARSHIPS

The Scholarship Selection Committee of the Society of British Aircraft Constructors and the Royal Aeronautical Society have made awards of Society of British Aircraft Constructors' Scholarships to the following:—

V. A. B. Rogers (nominated by The Fairey Aviation Co. Ltd.), Scholarship to College of Aeronautics, Cranfield.

E. L. Goldsmith (nominated by Short Bros. Ltd.), Scholarship to Imperial College of Science.

Keith G. Hodson, Educational Grant to the de Havilland Aircraft Co. Ltd.

Amy Johnson Scholarship—Awarded to Miss P. Fitzwater.

WILBUR WRIGHT MEMORIAL LECTURE

The Thirty-fourth Wilbur Wright Memorial Lecture was read by Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S., on "Recent Aerodynamic Developments." A full report of this lecture was published in the Journal of the Society for June 1946.

BRITISH COMMONWEALTH AND EMPIRE LECTURE

The Second British Commonwealth and Empire Lecture was read by Sir Henry Self, K.C.M.G., K.B.E., C.B., on "The Status of Civil Aviation in 1946." A full report of this lecture was published in the Journal of the Society for October 1946.

LECTURES

The following lectures were arranged during 1946:—

13th February 1946—Selection of Engineering Personnel for the Aircraft Industry, by Mr. F. Holliday, B.Sc., F.P.S., A.F.R.Ae.S.

28th February 1946—The Application of Radio to Civil Aviation, by Sir Robert Watson-Watt, C.B., Ll.D., F.R.S., F.R.Ae.S.

13th March 1946—Discussion on the Gas Turbine. A Full-Day Discussion at which the following papers were read:—

The Application of the Gas Turbine to Aircraft Propulsion, by Dr. S. G. Hooker.

Turbine-Compounding of the Piston Aero-Engine, by Dr. H. Ricardo, F.R.S., F.R.Ae.S.

The Application of the Gas Turbine in its Forms to the Field of Commercial Aviation, by Mr. R. M. Clarkson, F.R.Ae.S.

The Application of the Gas Turbine in its Forms to the Field of Military Aviation, by Mr. W. G. Carter, F.R.Ae.S.

28th March 1946—The Electrical Measurement of Strain, by Dr. S. C. Redshaw, F.R.Ae.S.

10th April 1946—The Silencing of Aircraft, by Mr. N. Fleming, M.A.

25th April 1946—Modern Aeronautical Materials, by Dr. L. Aitchison, F.R.Ae.S.

9th October 1946—A Critical Review of German Research on High-Speed Air Flow, by Mr. R. Smelt, M.A., A.F.R.Ae.S.

23rd October 1946—The Problems of Blind Landing, by Mr. H. F. Pritchard.

31st October 1946—Aeroelastic Problems at High Speed, by Professor A. R. Collar, M.A., B.Sc., F.R.Ae.S.

14th November 1946—Discussion on Engineering Problems of Future Aircraft. A Full-Day Discussion at which the following papers were read:—

Power Installations, by Mr. F. M. Owner, F.R.Ae.S.

Tailless Aircraft, by Mr. G. H. Lee, A.F.R.Ae.S.

Flying Boats, by Mr. C. P. T. Lipscomb, F.R.Ae.S.

Large Aircraft, by Mr. A. E. Russell, F.R.Ae.S.

29th November 1946—Joint Meeting with the Institution of Mechanical Engineers. Aircraft Propulsion, by Major F. M. Green and Mr. J. E. Wallington.

5th December 1946—Protection of Aircraft Against Ice, by Mr. J. K. Hardy.

11th December 1946—Photolofting, by Mr. S. P. Woodley.

19th December 1946—The Evolution of the Spitfire, by Mr. J. Smith.

ADVISORY COMMITTEE

The Council wish to place on record the remarkable work of the Advisory Committee of the Society which served the Ministers of Aircraft Production from 1941 to 1946. The following extract from the Principal Private Secretary to the Minister in 1941 indicates the nature of the work of the Committee.

> "Colonel Moore-Brabazon has asked me to say that he would like to explore the possibility of making more use of the Society in the way of advice on technical problems of interest in the development of aeronautics. The Minister has in mind the possibility that the Council of the Society would set up a Committee of six or seven prominent technical representatives of the aeronautical industry to whom he could refer any problem for advice.
>
> "It will be appreciated that matters of the highest secrecy might fall to be discussed with such a Committee and therefore, in the event of the Council agreeing to the proposal, perhaps you would arrange for the suggested composition of the Committee to be referred to the Minister."

The following were appointed: Major T. M. Barlow, Mr. S. Camm, Sir Roy Fedden, Mr. A. Gouge, Mr. E. W. Hives, Mr. R. K. Pierson and Mr. C. C. Walker. Because of pressure of work Mr. Hives and Major Barlow were unable to continue with the work of the Committee. Major F. B. Halford, Mr. Roy Chadwick and Dr. L. Aitchison were added. Sir Roy Fedden acted as Chairman and Captain J. Laurence Pritchard as Secretary of the Committee throughout the five years of its activity.

During those five years the Committee prepared nearly forty highly secret memoranda on war problems and had the benefit of the advice of the leading authorities in their subjects in this country and America, as well as receiving the greatest co-operation from official establishments and firms in the Industry.

The work of this Committee, to which it has not previously been possible to make reference because of its highly secret nature, was of considerable value. The Committee met the Ministers once a month and the value of the work they did may best be summed up by the following extract from a letter to its Chairman from Lord Brabazon:—

> "The Royal Aeronautical Society and especially those Members who gave their time at so difficult a period in the war are to be congratulated and thanked for what they did to bring about the successful air triumph."

BRANCHES

There has been a gratifying increase in the activities of the Branches during the year. The total membership of the Branches is more than 5,000, and the number of the Branches is 24, of which 19 are in Great Britain and five in the British Commonwealth and Empire.

Mr. N. E. Rowe, one of the Vice-Presidents of the Society, has been given special charge of the Branches and is now paying a visit to each one in turn to obtain their views, not only on all matters affecting the Branch organisation, but particularly with regard to keeping in closer contact with the main Society.

The results of his work are already beginning to show. The Council have in mind a considerably closer relationship between the Branches themselves as well as with the main body and have already received many useful suggestions to further these ends, from the Branches.

GRADUATES' AND STUDENTS' SECTION

Interest in the Graduates' and Students' Section activities continued to grow during the year and the attendance at technical meetings averaged 75, which is the highest on record. During the session, which began with the Annual General Meeting on 29th March 1946, the Section held nine technical meetings and made six visits. The Section's first dance was held in January and received wide support.

Committee

The affairs of the Section have been managed during this session by a Committee consisting of the following:—E. J. N. Archbold, Graduate, Chairman; J. Spillman, Graduate, Vice-Chairman; K. R. Obee, Graduate; J. W. F. Housego, Graduate; R. L. E. Toms, Graduate; P. Jenner, Student; S. P. Ellis, Graduate; L. Wookey, Student; J. Hands, Graduate; P. L. Cronbach, Associate Fellow, *ex-officio* member; J. G. Roxburgh, Graduate, Hon. Secretary; E. H. Bond, Student, Assist. Hon. Secretary.

The Committee accepted with regret the resignation of Mr. J. Spillman on his leaving the London area.

Technical Meetings

The following meetings have been held during the session:—

23rd January 1946—Low Drag Aerofoils, by Dr. L. G. Whitehead, Ph.D., A.F.R.Ae.S.

7th February 1946—Technical Activities—A Discussion led by Dr. D. M. A. Leggett, A.F.R.Ae.S.

26th February 1946—Tailless Aircraft, by Mr. G. H. Lee, A.F.R.Ae.S.

20th March 1946—Film Show: Radar.

16th April 1946—Flight Refuelling, by Sir Alan Cobham, K.B.E., A.F.C., Hon.F.R.Ae.S.

2nd May 1946—Transport Aircraft, by F. Radcliffe, F.R.Ae.S.

3rd October 1946—Discussion on The Design of Wings, Part I., introduced by:—

Mr. E. J. N. Archbold, B.Sc., Grad. R.Ae.S.: The Aerodynamic Design of Wings.

Mr. R. L. E. Toms, Grad. R.Ae.S.: Wing Stiffness.

Mr. J. Spillman, Grad. R.Ae.S.: Wing Weight.

15th October 1946—Discussion on The Design of Wings, Part II, introduced by:—
Mr. K. R. Obee, Grad. R.Ae.S.: Wing Testing.
Mr. J. W. F. Housego, Grad. R.Ae.S.: Swept-Back Wings.

30th October 1946—The Application of the Wind Tunnel to Aircraft Design, by Mr. E. J. Richards, A.F.R.Ae.S.

21st November 1946—Structures in Aircraft Design, by R. H. Sandifer, F.R.Ae.S.

3rd December 1946—Show of Captured German Films, lent by the Ministry of Supply, at the British Council Theatre. Commentary by E. C. Howes, Esq.

In addition, the Section has received invitations to attend meetings of the Helicopter Association of Great Britain, and of the Society of Licensed Aircraft Engineers.

Visits

The following visits were made by members of the Section:—

6th and 13th July 1946—Fairey Aviation Co. Ltd., Hayes.

17th August 1946—Short Bros. Ltd., Rochester.

24th August 1946—No. 160 Staging Post, Transport Command, Royal Air Force, Blackbushe Aerodrome.

28th September 1946—National Physical Laboratory, Teddington.

9th November 1946—D. Napier and Son Ltd., and Percival Aircraft Ltd., Luton.

Work of Committee

In addition to arranging the Section's activities, the Committee discussed at one of its meetings anomalies in the granting of Student and Graduate Memberships. As a result it recommended that, in regard to the examinations which give exemption from the Associate Fellowship Examination, the Pass Degree in aeronautical subjects should be considered equal in standard to the Higher National Certificate in aeronautical subjects. The Committee also raised the matter of the establishment of a Higher National Certificate in Aeronautical Engineering and the adoption of uniform standards for this examination throughout the country.

Social Activities

The first dance to be held by the Section took place on 10th January 1947 at the Paviour's Arms, Westminster, and was most successful.

Acknowledgments

The Section wishes to express its gratitude to Captain Pritchard for his ever present support and encouragement, and to the staff of the Society for their invaluable assistance.

The Section also wishes to record its thanks to the managements of Fairey Aviation Co. Ltd., Short Bros. Ltd., D. Napier and Son Ltd., and Percival Aircraft Ltd., to the A.O.C.-in-C. Transport Command R.A.F., and to the Director of the National Physical Laboratory for their kind permission to arrange visits to their establishments and to all those who helped to ensure the success of these visits.

The Section wishes to express its sincere thanks to those who have prepared and read papers before the Section, and to Captain Pritchard and Dr. Leggett for taking the chair at the meetings on 3rd and 15th October respectively.

In conclusion, the Section wishes to thank the Helicopter Association of Great Britain and the Society of Licensed Aircraft Engineers for inviting members of this Section to their lectures.

ASSOCIATE FELLOWSHIP EXAMINATIONS

There is again a marked increase in the numbers of candidates taking the examination, both in this country and various centres abroad.

The following were successful in the Associate Fellowship Examinations held in May 1946:—

J. M. Allwright, Applied Mathematics, Theory of Internal Combustion Engines; E. H. Amor, Aircraft Materials; J. A. Anderson, Applied Mathematics; G. E. Archdale, Pure Mathematics (1st Place); C. R. Baines, Theory of Internal Combustion Engines (1st Place); J. C. Barrett, Pure Mathematics; G. B. Bhide, Pure Mathematics, Aircraft Materials (1st Place); G. W. Bleasdale, Applied Mathematics (1st Place); D. R. Blundell, Aerodynamics; G. Boyce, Applied Mathematics; P. C. G. Brazier, Strength of Aeronautical Materials and Structures; R. P. Castle, Strength of Aeronautical Materials and Structures; D. C. Chappel, Pure Mathematics; J. R. Combley, Pure Mathematics; P. R. Dymond, Pure Mathematics; P. Ebershardt, Design (Aircraft); G. D. Evans, Applied Mathematics, Aircraft Instruments (1st Place); J. R. C. Fearon, Pure Mathematics, Theory of Machines; A. H. Fernando, Applied Mathematics; G. Gallia, Theory of Machines; P. L. E. Gallimore, Pure Mathematics; E. B. Garlah-Watkins, Aircraft Instruments; M. A. Glasspole, Pure Mathematics; E. M. Harris, Pure Mathematics, Strength of Aeronautical Materials and Structures, Aerodynamics; D. S. Haldipur, Applied Mathematics; N. T. W. Harper, Applied Mathematics; P. A. Hatswell, Pure Mathematics; P. A. Hearne, Aerodynamics; E. Hobart, Applied Mathematics, Aerodynamics, Theory of Machines (1st Place); J. A. Howard, Design (Aero-Engines); K. T. Jackson, Theory of Internal Combustion Engines; A. James, Applied Mathematics, Aerodynamics, Design (Aircraft); R. Kendall, Theory of Machines; P. G. Kendrick, Navigation; G. G. Legg, Design (Aircraft); A. MacDonald, Aerodynamics, Design (Aero-Engines) (1st Place); G. McIntosh, Pure Mathematics; J. G. Mason, Pure Mathematics, Strength of Aeronautical Materials and Structures (1st Place), Aerodynamics (1st Place); D. J. Mead, Aerodynamics; O. R. B. Moorman, Strength of Aeronautical Materials and Structures, Design (Aircraft); R. May, Pure Mathematics; H. M. Nerriere, Applied Mathematics, Design (Aero-Engines); P. I. D. O'Brien, Pure Mathematics; A. E. Polden, Theory of Internal Combustion Engines; F. B. Perry, Pure Mathematics, Design (Aircraft); J. L. Raynes, Applied Mathematics; H. Rewitch, Theory of Internal Combustion Engines; N. Ring, Applied Mathematics, Strength of Aeronautical Materials and Structures, Design (Aircraft) (1st Place); F. H. Robertson, Design (Aircraft); G. L. Ronson, Theory of Machines; D. K. Saunders, Pure Mathematics; E. Slap, Applied Mathematics; B. L. Sowry, Applied Mathematics, Design (Aircraft); P. E. A. Stevenson, Theory of Internal Combustion Engines; R. S. Sowter, Applied Mathematics; P. D. Walters, Pure Mathematics; J. Watkins, Theory of Internal Combustion Engines; J. K. Yates, Air Transport; L. Young, Pure Mathematics, Theory of Internal Combustion Engines, Theory of Machines.

The following were successful in the Associate Fellowship Examination held in December 1946:—

Allwright, J. M., Theory of Machines; Balasubramanian, M. S., Applied Mathematics; Balasubramanian, T. S., Theory of Internal Combustion Engines; Busen-Schmitz, H., Pure Mathematics; Briginshaw, G. F., Air Transport; Bukovsky, J. J., Navigation and its Application to Aeronautics; Carroll, T. D. R., Applied Mathematics, Strength of Aeronauti-

cal Materials and Structures, Navigation and its Application to Aeronautics; Clarke, J. F., Applied Mathematics, Theory of Machines; Cook, H., Applied Mathematics, Theory of Machines; Currey, N. S. Pure Mathematics; Dolezal, J., Strength of Aeronautical Materials and Structures, Design (Aircraft) (1st Place); Donkin, A., Applied Mathematics, Strength of Aeronautical Materials and Structures, Aerodynamics; Dowlen, E. M., Applied Mathematics (1st Place), Strength of Aeronautical Materials and Structures (1st Place), Aerodynamics (1st Place); Dunn, K. G., Aircraft Materials; East, A. W., Pure Mathematics; Edwards, P. A., E., Pure Mathematics; Eggington, W. J., Applied Mathematics; England, B. H., Aircraft Materials (1st Place); Evans, R. J., Applied Mathematics; Fairbrother, A., Strength of Aeronautical Materials and Structures, Design (Aircraft); Fearon, J. R. C., Strength of Aeronautical Materials and Structures; Gilchrist, J., Pure Mathematics; Gill, D., Pure Mathematics; Glasspole, M. A., Theory of Machines; Glew, F., Pure Mathematics; Greer, A., Strength of Aeronautical Materials and Structures; Harper, N. T. W., Theory of Machines; Harris, E. L., Applied Mathematics, Strength of Aeronautical Materials and Structures, Design (Aircraft); Hellier, E. J., Aerodynamics; Henry, A., Applied Mathematics; Hawley, A. V., Applied Mathematics, Strength of Aeronautical Materials and Structures, Theory of Machines; Jones, J. G., Design (Aero-Engines), Theory of Machines; Legg, G. G., Pure Mathematics, Strength of Aeronautical Materials and Structures; Lewandowski, A., Applied Mathematics, Theory of Machines; Little, G. W., Design (Aircraft), Applied Mathematics; Macewicz, K., Applied Mathematics; Marshall, J. M., Applied Mathematics, Theory of Machines; Measures, A., Pure Mathematics; McCallum, R. L., Applied Mathematics, Theory of Machines; McFarlane, P. R., Applied Mathematics, Design (Aero-Engines), Theory of Machines; Nayak, U. N., Pure Mathematics, Aircraft Instruments (Theory and Design); Page, D. G., Applied Mathematics, Design (Aero-Engines), Theory of Machines; Piggott, J. W., Applied Mathematics, Theory of Internal Combustion Engines; Ricketts, G. C., Strength of Aeronautical Materials and Structures; Romeril, J. G., Applied Mathematics; Scott, C. L. M., Applied Mathematics, Navigation (1st Place), Aerodynamics; Smith, M. C. G., Aerodynamics; Sowry, B. L., Theory of Internal Combustion Engines; Staples, G. E., Applied Mathematics, Design (Aero-Engines), Theory of Machines (1st Place); Sweeting, N. E., Pure Mathematics (1st Place), Theory of Machines, Aerodynamics; Swingler, J. A. Applied Mathematics; Subbarao, H. V., Design (Aero-Engines); Szymanski, R., Theory of Machines; Tavener, R. I. B., Theory of Machines; Taylor, A. M., Design (Aero-Engines), Theory of Machines; Titmuss, H., Applied Mathematics, Aircraft Materials; Tuffs, P. J. W., Pure Mathematics, Strength of Aeronautical Materials and Structures; Walmsley, J. H., Applied Mathematics; Watkins, J., Design (Aero-Engines) (1st Place); Williams, W. S., Applied Mathematics.

EIGHTIETH ANNIVERSARY

On 11th January 1946 a dinner was held in Guildhall in celebration of the Eightieth Anniversary of the founding of the Society. It was followed by a Reception by the President and Council at the Society's headquarters on 12th January 1946, and by celebrations by many of the Branches.

A full report of the celebrations was given in the February 1946 Journal together with messages from H.M. The King, Patron of the Society; The Rt. Hon. C. R. Attlee, the Prime Minister; the Rt. Hon. Winston Churchill, and many others.

In connection with the celebrations an illustrated history of the Society during the past eighty years was published.

FARNBOROUGH EXHIBITION AND FLYING DISPLAY

In June 1946 the Royal Aircraft Establishment arranged an Exhibition of British aircraft and engines and a flying display at Farnborough, and also opened the Radio and Structures Department. By the courtesy of the Director, Saturday 29th June 1946 was set aside for members of the Society and their guests.

The Exhibition, one of outstanding interest, was attended by more than 1,500 members of the Society and their friends, and the Council wish to place on record their appreciation of the facilities which were extended to the Society on this occasion.

GARDEN PARTY

By the kindness of the Society of British Aircraft Constructors and the President, Sir Frederick Handley Page, the Society's annual Garden Party was renewed at Radlett Aerodrome on Sunday 15th September 1946.

The Society of British Aircraft Constructors and the aircraft and accessory companies concerned, some two hundred in all, generously agreed to keep their Display and Exhibition in being specially for members of the Society and their friends. The President of the Society, Sir Frederick Handley Page, kindly consented to make the aerodrome at Radlett available to the Society for the day.

More than 6,000 members and their guests attended, and the Council wish to place on record the thanks of all members of the Society to the outstanding help given to the Society by the Society of British Aircraft Constructors, to the many firms in the Industry which provided the static display and the flying exhibition, to the aerodrome staff, and to the pilots who gave such a remarkable flying display.

GIFTS TO THE SOCIETY

The Council gratefully acknowledge the gift of books, photographs, historical papers, lantern slides and airmail covers and stamps during the year. All gifts have been acknowledged as received in the Monthly Notices of the Journal.

The Council particularly wish to draw attention to the following items which have been acquired during the year:—

In August Mrs. Lanchester presented to the Society Dr. Lanchester's original flying models with which he experimented in June 1894. These models are of great historic interest. Designed before any man flew, from them Dr. Lanchester built up his theory of flight in his two astonishing volumes "Aerodynamics" and "Aerodonetics," published in 1907 and 1908.

Later in the year Sir Kenelm Cayley agreed to let the Society have on permanent loan the notebooks and papers of his grandfather, Sir George Cayley, the "father of British Aeronautics." These notebooks and papers are unique in the history of aviation.

About the same time the Society acquired one of Stringfellow's original steam engines which was used in his early flying models and his original letters and documents of the period. One of them gives, in Stringfellow's handwriting, the results of tests he made with this engine in 1842.

The Society has many historical relics of the past hundred years and it is hoped to prepare a small exhibition of them which will be sent to each of the Branches in turn.

Continued on page 470.

THE ROYAL

(Aerial

Balance Sheet,

£ s. d. 1945 Figures		£ s. d.	£ s. d.
	Share Capital—		
	Authorised—		
	20 Shares of 1/- each	1 0 0	
	999 Shares of £1 each	999 0 0	
		1000 0 0	
19 0	*Issued*—19 Shares of 1/- each, fully paid	... ...	19 0
4094 1 4	*Sundry Creditors*	... ...	4447 19 0
1858 1 9	*Subscriptions and Other Amounts Received in Advance*	... ...	1910 12 11
4853 17 4 (Pension Fund)			
5183 16 0	*Publications Development Account*	... ...	6187 19 4
	Income and Expenditure Account—		
2576 17 10	Balance at 31st December, 1945	3096 8 11	
	Add—Transfer from Staff Pension Fund	4853 17 4	
519 11 1		7950 6 3	
3096 8 11	*Add*—Surplus of Income over Expenditure for year to date ...	1307 7 4	9257 13 7
19087 4 4	F. HANDLEY PAGE, *President.* C. F. UWINS, *Hon. Treasurer.*		£21805 3 10

We report to the Members that we have examined the above Balance Sheet with the Books and are of opinion that the Balance Sheet is properly drawn up so as to exhibit a true and correct information and the explanations given to us and as shown by the books of the Society.

3, Frederick's Place, Old Jewry, London, E.C.2.
25th March 1947.

Income and Expenditure Account

£ s. d. 1945 Figures.		£ s. d.	£ s. d.
	To Establishment Expenses—		
1654 10 11	Ground Rent, Heating, Lighting and Insurance and Repairs, etc.		1645 9 0
	,, Office and Staff Expenses—		
5279 2 11	Salaries	6538 12 9	
1083 7 0	Printing and Stationery	1278 5 3	
752 0 3	Postages and Telephone	918 17 2	
970 16 8	Other Charges	1070 18 2	9806 13 4
8085 6 10			
242 17 2	,, Meetings	... ...	437 15 0
574 9 0	,, Library Expenses	... ...	551 4 1
128 11 6	,, Branch Expenses	... ...	114 12 6
325 9 3	,, Prizes and Donations	... ...	96 13 4
507 10 2	,, Dinners and Receptions	... ...	208 8 3
278 5 0	,, Legal and Professional Charges	... ...	159 12 6
1000 0 0 (Staff Pension Fund)	,, Staff Pension Premiums	... ...	524 12 4
	,, Examinations—Expenses	530 17 2	
——	*Less*—Fees received	355 9 6	175 7 8
519 11 1	,, Balance being Surplus of Income over Expenditure for year carried to Balance Sheet		1307 7 4
13316 10 11			£15027 15 4

AERONAUTICAL SOCIETY

Science Limited)

31st December, 1946.

£ s. d. 1945 Figures		£ s. d.	£ s. d.
	Printed Books, Bindings, Old Prints, etc., at cost, less amounts written off, as at 31st December, 1945		50 0 0
1 0 0	*Stock of* JOURNALS *and other Publications*, as at 31st December, 1945		1 0 0
	Investment in and amount due from Subsidiary Company—		
	Aeronautical Trusts Limited—		
1 1 0	21 Shares of 1/- each, fully paid, at cost	1 1 0	
1539 2 2	Amount due from Royal Aeronautical Society Endowment Fund	2136 5 5	2137 6 5
1540 3 2			
	Investments at Cost—		
	£2335 10s. 7d. 2½ % Funding Loan, 1956/61	2201 4 2	
4000 0 0	£4550 0s. 0d. 3 % Savings Bonds, 1960/70	4550 0 0	
4853 17 4 (Pension Fund)	£1050 3 % Savings Bonds 1965/75	1050 0 0	7801 4 2
4009 12 6	*Sundry Debtors*	... ...	5674 3 4
4526 6 4	*Cash at Bank and in Hand*	... ...	6141 9 11
106 5 0 (Rent in Advance)			
19087 4 4			£21805 3 10

of the Society, and have obtained all the information and explanations we have required. We view of the state of the Society's affairs as at 31st December, 1946, according to the best of our

(Signed) PRICE, WATERHOUSE & CO.

for the Year ending 31st December, 1946.

£ s. d. 1945 Figures			£ s. d.	£ s. d.
10313 13 0	By Annual Subscriptions	... ...		12072 8 9
250 0 0	,, Donations	... ...		250 0 0
	,, Interest on Investments (Gross)		122 14 6	
60 0 0	,, ,, ,, ,, (*less* Tax)		55 16 2	
118 15 4	,, Income Tax Recovered		30 0 0	
2448 1 5	,, Interest on Endowment Fund Investments (*less* expenses)		2496 15 11	2705 6 7
2626 16 9				
	,, JOURNAL and Sundry Publications—			
3187 15 10	Sales		3525 11 0	
11366 14 4	Advertisement Revenue		10486 0 0	
14454 10 2			14011 11 0	
6315 19 0	*Less*—Printing Costs	8941 2 11		
500 0 0	Special Publications	625 19 7		
586 5 6	Postages	878 7 3		
1968 9 8	Other Charges	2561 17 11	13007 7 8	
9370 14 2				
5183 16 0			1004 3 4	
5183 16 0	*Less* Amount transferred to Publications Development Account ...		1004 3 4	
126 1 2 (Examinations)				
13316 10 11				£15027 15 4

AERONAUTICAL

Balance Sheet,

	£ s. d.	£ s. d.	£ s. d.
Share Capital—			
Authorised—40 Shares of 1/- each		2 0 0	
Issued—21 Shares of 1/- each fully paid			1 1 0
Royal Aeronautical Society Endowment Fund—			
Capital Account—Balance at 31st December, 1945 ...		125975 18 6	
Add—Donations received during year		417 3 5	
Entrance Fees received during year		1526 14 6	
		127919 16 5	
Income Account—Accumulated Surplus at 31st December, 1945		5799 17 3	133719 13 8
Pilcher Memorial Fund—			
Capital Account—As at 31st December, 1945		99 14 0	
Income Account—Balance at 31st December, 1945 ...	55 11 0		
Add—Income for year to date	4 0 8	59 11 8	159 5 8
Usborne Memorial Fund—			
Capital Account—As at 31st December, 1945		109 2 5	
Income Account—Balance at 31st December, 1945 ...	72 1 0		
Less—Excess of Expenditure over Income for year to date	1 6 0	70 15 0	179 17 5
Herbert Akroyd Stuart Fund—			
Capital Account—As at 31st December, 1945		688 19 0	
Income Account—Balance at 31st December, 1945 ...	426 5 5		
Add—Income for year to date	31 8 0	457 13 5	1146 12 5
R.38 Memorial Fund—			
Capital Account—As at 31st December, 1945		978 3 10	
Income Account—Balance at 31st December, 1945 ...	*708 4 9		
Add—Income for year to date	47 3 10	755 8 7	1733 12 5
Edward Busk Memorial Fund—			
Capital Account—As at 31st December, 1945		449 6 1	
Income Account—Balance at 31st December, 1945 ...	200 5 11		
Add—Income for year to date	19 18 11	220 4 10	669 10 11
Wilbur Wright Memorial Fund—			
Capital Account—As at 31st December, 1945		2136 17 11	
Income Account—Balance at 31st December, 1945 ...	189 19 2		
Less—Excess of Expenditure over Income for year to date	1 7 2	188 12 0	2325 9 11
Simms Gold Medal Fund—			
Capital Account—As at 31st December, 1945		524 15 9	
Income Account—Balance at 31st December, 1945 ...	32 18 9		
Add—Income for year to date	15 0 0	47 18 9	572 14 6
Alston Memorial Fund—			
Capital Account—As at 31st December, 1945		245 6 0	
Income Account—Balance at 31st December, 1945 ...	37 17 7		
Add—Income for year to date	7 19 0	45 16 7	291 2 7
			£140799 0 6

F. HANDLEY PAGE, *President.*
C. F. UWINS, *Hon. Treasurer.*

We report to the Members of Aeronautical Trusts Limited, that we have examined the above explanations we have required. We are of opinion that the Balance Sheet is properly drawn up December, 1946, according to the best of our information and the explanations given to us and as

3, Frederick's Place, Old Jewry, London. E.C.2.
25th March 1947.

TRUSTS LIMITED

31st December, 1946

	£ s. d.	£ s. d.
Cash in Hand		1 1 0
Royal Aeronautical Society Endowment Fund—		
Leasehold Property at Cost—Less amounts written off		
4, 8, and 9, Hamilton Place	8245 0 0	
Furniture at cost, *less* depreciation	2671 17 6	
Investments at Cost—	£ s. d.	
£21081 19s. 1d. 3½ % Conversion Stock	21698 2 7	
£87235 12s. 5d. 3 % Savings Bonds, 1965/75	87801 17 2	
£7000 2½ % Savings Bonds, 1964/67	7331 10 6	
£1000 3 % Defence Bonds	1000 0 0	
£4100 L.N.E. Rly. 3 % Debenture Stock	3162 6 3	
£3100 L.M.S. Rly. 4 % Debenture Stock	3162 19 9	124156 16 3
Cash at Bank	624 8 10	
Amounts due for refund of Income Tax — ...	157 16 6	
	135855 19 1	
Less—Amount due to Aerial Science Limited ...	2136 5 5	133719 13 8
Pilcher Memorial Fund—		
£115 6s. 10d. 3½ % War Loan at cost	116 5 0	
Cash at Bank	43 0 8	159 5 8
Usborne Memorial Fund—		
£113 3½ % War Loan at cost	114 11 1	
Cash at Bank	65 6 4	179 17 5
Herbert Akroyd Stuart Fund—		
£683 1s. 0d. 3½ % War Loan at cost	698 19 0	
£250 3 % Defence Bonds at cost	250 0 0	
	948 19 0	
Cash at Bank	197 13 5	1146 12 5
R.38 Memorial Fund—		
£1048 11s. 2d. 3½ % War Loan at cost	1098 18 10	
£350 3 % Defence Bonds at cost	350 0 0	
	1448 18 10	
Cash at Bank	284 13 7	1733 12 5
Edward Busk Memorial Fund—		
£284 4s. 2d. 3½ % War Loan at cost	284 4 2	
£217 London Transport 4½ % "A" Stock, at cost	199 4 6	
	483 8 8	
Cash at Bank	186 2 3	669 10 11
Wilbur Wright Memorial Fund—		
£1246 18s. 1d. 3½ % Conversion Stock, at cost	1000 0 0	
£1242 16s. 10d. 3 % Savings Bonds, 1965/75 at cost	1250 14 9	
	2250 14 9	
Cash at Bank	74 15 2	2325 9 11
Simms Gold Medal Fund—		
£300 3% Defence Bonds, at cost	300 0 0	
£200 3 % Savings Bonds, 1960/70, at cost	200 0 0	
	500 0 0	
Cash at Bank	72 14 6	572 14 6
Alston Memorial Fund—		
£252 14s. 10d. 3 % War Loan 1955/59 at cost	250 0 0	
Cash at Bank	41 2 7	291 2 7
		£140799 0 6

Balance Sheet with the books of the Company and have obtained all the information and so as to exhibit a true and correct view of the state of the Company's affairs as at 31st shown by the books of the Company.

(Signed) PRICE, WATERHOUSE & CO.

AERONAUTICAL

INCOME & EXPENDITURE ACCOUNTS

Royal Aeronautical Society

	£ s. d.
To Legal Charges	4 4 0
,, Amortisation of Leasehold Property	485 0 0
,, Depreciation of Furniture	213 15 0
,, Surplus of Income over Expenditure for year transferred to Aerial Science Limited	2496 15 11
	£3199 14 11

Pilcher

To Income for year carried to Balance Sheet...	4 0 8
	£4 0 8

Usborne

To 1946 Award	5 5 0
	£5 5 0

Herbert Akroyd

To Income for year carried to Balance Sheet	31 8 0
	£31 8 0

R.38

To Income for year carried to Balance Sheet	47 3 10
	£47 3 10

Edward Busk

To Income for year carried to Balance Sheet...	19 18 11
	£19 18 11

Wilbur Wright

To 1946 Award	75 0 0
	£75 0 0

Simms Gold

To Income for year carried to Balance Sheet	15 0 0
	£15 0 0

Alston

To Income for year carried to Balance Sheet...	7 19 0
	£7 19 0

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER, 1946

Endowment Fund.

	£	s.	d.
By Interest on Investments (gross)	256	12	2
,, ,, ,, ,, (*less* Tax)...	1772	0	11
,, Refund of Income Tax	1171	1	10
	£3199	14	11

Memorial Fund.

	£	s.	d.
By Interest on Investments (gross)	4	0	8
	£4	0	8

Memorial Fund.

	£	s.	d.
By Interest on Investments (gross)	3	19	0
,, Excess of Expenditure over Income for the year carried to Balance Sheet	1	6	0
	£5	5	0

Stuart Fund.

	£	s.	d.
By Interest on Investments (gross)	31	8	0
	£31	8	0

Memorial Fund.

	£	s.	d.
By Interest on Investments (gross)	47	3	10
	£47	3	10

Memorial Fund.

	£	s.	d.
By Interest on Investments (gross)	9	18	10
,, ,, ,, ,, (*less* Tax)	5	2	7
,, Refund of Income Tax	4	17	6
	£19	18	11

Memorial Fund.

	£	s.	d.
By Interest on Investments (gross)	48	11	8
,, ,, ,, ,, (*less* Tax)...	16	19	6
,, Refund of Income Tax	8	1	8
,, Excess of Expenditure over Income for year carried to Balance Sheet	1	7	2
	£75	0	0

Medal Fund.

	£	s.	d.
By Interest on Investments (gross)	15	0	0
	£15	0	0

Memorial Fund.

	£	s.	d.
By Interest on Investments (*less* Tax)...	4	3	4
,, Refund of Income Tax	3	15	8
	£7	19	0

Continued from page 463.

FINANCE

The Income and Expenditure Accounts and Balance Sheets of Aerial Science Ltd. and Aeronautical Trusts Ltd. for 1946 are published with this report.

JOURNAL COMMITTEE

The Council wish to place on record the excellent work done by the Journal Committee under the Chairmanship of Mr. G. H. Dowty. The Committee has been handicapped by paper restrictions and the increasing costs of printing, but it is hoped as these restrictions are removed to extend the scope of the Journal and enlarge it. Despite the difficulties there is an increased outside sales which may be considered to be a satisfactory indication of the increasing value of the Journal as a record of technical aeronautical progress.

OFFICERS AND COMMITTEES

The Council wish to place on record their appreciation of the work which has been done by the Honorary Officers of the Society during the year.

Captain C. F. Uwins, F.R.Ae.S., the Honorary Treasurer, has given invaluable advice and help on financial matters.

Mr. J. E. Hodgson, Honorary Librarian for so many years, has again during the year 1946 continued to advise the Society on all matters pertaining to the Library.

The Council wish to place on record particularly their appreciation of the work of the various Committees. Much of the work being done by certain of the Committees has involved many meetings during the year and the results which they have achieved will prove of great value to the Society.

OBITUARIES

Major R. H. Archbald (Fellow)
Sir James Bird (Fellow)
P. H. Campion (Associate Fellow)
Captain H. G. Casey (Associate Fellow)
A. E. L. Chorlton (Fellow)
J. C. Evans (Associate)
Mrs. Rosamund Everard-Steenkamp (Associate)
F. B. Ford (Associate Fellow)
S/Ldr. E. Bagley Gale (Companion)
Dr. F. W. Lanchester (Honorary Fellow)
Miss H. M. Lyon (Associate Fellow)
F/Sgt. R. Mackinder (Student)
S/Ldr. G. O. Manning (Associate)
P. Maxwell-Muller (Associate Fellow)
F/Lt. C. J. Merryful (Associate)
G. B. Moncrieff-Yeates (Associate)
Mrs. Dorothy Pearse (Associate)
S/Ldr. R. C. I. Pearse (Associate)
Lt. Comdr. (A.) R. B. Pearson, R.N. (Associate)
W/O. J. V. Saunders (Associate Fellow)
Lt.-Col. E. M. Sinauer (Associate Fellow)
T. R. Thomas (Fellow)
J. V. P. Williams (Associate Fellow)
Captain T. F. Wilson (Associate Fellow)
Dr. M. A. A. Zahra (Fellow)

CORRESPONDENCE

ON DESIGN FOR MAINTENANCE

by

Lieut. (A/E) T. E. G. BOWDEN, R.N., Grad.R.Ae.S. *(March 1947 Journal).*

As one whose duty it is to put on paper instructions for the maintenance and servicing of aircraft, I have seen many instances where slipshod design features have made it almost impossible for maintenance to be accomplished quickly, easily, and in a logical order. Often, having given instructions after studying the production drawings, examination of the actual aircraft has shown that a particular component could not be serviced through the specified access panel or by using the special tools designed for the operation. Such tools, and here I agree that they should be abolished as far as possible, sometimes are too flimsy for their duties and fail after limited use.

When rigging flying controls the seeds of theoretical design bring forth a crop of associated difficulties. The use of rigging boards seems to be necessary but, speaking from the Maintenance Manual viewpoint, although surface movements are generally given in linear dimensions, cases still occur where the movements of intermediate levers in the cable run are stated in degrees, making the use of a clinometer and levelling boards essential. One instance of careless thinking in the drawing office made it necessary for a complicated jig to be used for checking a small dimension every time one control surface was rigged.

Lieutenant Bowden's remarks about the ground handling of aircraft are appropriate. To curtail a ground crew from exerting force on weak points of the airframe I suggest that members of this organisation be given an elementary course of training dealing with the basic principles of construction. Although the instructions painted on machines are generally followed, in practice detachable components are often carelessly handled. I think this is because of the psychological effect that such parts, when painted, have the nature of their constructional materials disguised and consequently look extremely strong, with the result that they are treated accordingly.

Dealing with the production side of this problem it appears paradoxical that the result of so much highly skilled thinking and work, an aircraft, is usually handled in the experimental flight shed by labourers or other men who are unaware of the fragile nature of their charge. I have seen aircraft of about 10,000 lb. tare weight wheeled from a hangar by such persons pushing on the trailing edges of the ailerons.

I think that all cockpit sides, even in single-seater military aircraft, should have an inner skin. Many draughtsmen consider such a skin as just something on which to put the cockpit paint but, from a servicing angle, it would prevent the lodgment of lost nuts, bolts, rivets, and swarf from drilled holes, behind flanged stringers and equipment brackets. As Lieutenant Bowden mentions, these bits and pieces may cause the jamming of vital controls because of vibration and aerobatics shifting them about the interior of the machine. Incidentally, where an inner skin is fitted, as in many civil transports, it does much to clean up the appearance of the cockpit.

The Technical Publications department is often closer to these problems than the Drawing Office, but it is seldom that suggestions for maintenance improvements put forward by this department are considered by the latter.

It is essential that sound maintenance standards be laid down at the initial design stage. If this is not done then the bad servicing points will become a constant source of embarrassment to the design staff when operations begin. In view of the lax maintenance provisions on present-day aircraft one is prompted to ask what is going to happen when we have to deal with aircraft of 100,000 and 200,000 lb. A.U.W. which will be arriving in the near future. Let not the design staffs be deceived by thinking that a larger airframe means that there will be more space available for maintenance operations; history shows that the larger the aircraft the more equipment, controls, and internal structural components are installed. Incidentally, for obvious reasons, pressurising will prevent access panels being located in the fuselage skin.

In the case of civil aircraft the operator, who is the customer and chooses his equipment on individual merit, will demand in future machines which can be maintained and overhauled quickly, to prevent loss of business due to them being grounded for long periods, and easily, to reduce the number of skilled engineers required and thus keep down overheads. The question of quick overhaul of military aircraft is so important that this point cannot be over-emphasised.

As a beginning towards improving maintenance, I suggest that a full-time committee be set up within the design organisation, consisting of two senior draughtsmen working in conjunction with the foreman of the flight shed, to examine all drawings affecting maintenance before issuing them to the shops. The committee should have authority to report back to the design staff all cases of awkward and clumsy servicing and to make suggestions for obviating such points. Later, this committee should be built up into a self-contained department not unattached from the main design office. It seems remarkable that this procedure has not already been accomplished; I humbly suggest that if Aerodynamic Departments had been set up fifteen years ago low-drag laminar flow aerofoils would have been common on pre-war aircraft.

As an ex-member of the same drawing office as Lieutenant Bowden, I congratulate him on his explicit summary of an important subject which has been pushed into the background.

B. Jackson, A.M.I.Ae.S., Associate.

Extensive experience on the maintenance and repair of all types of aircraft bears out much that Lt. Bowden said regarding poor design from the maintenance angle, and it is thought that an even stronger case might be presented calling for co-operation between designers, drawing office staffs, and practical engineers.

Advantages accruing from a design for maintenance policy would seem to be very real.

The modern aircraft is an expensive item of equipment which depreciates in value at an alarming rate, whether flown or not and the obvious policy for efficient economic operation is for a minimum holding of aircraft which must be kept at their task, *i.e.* in the air. Poor design from the engineering viewpoint keeps aircraft grounded for unnecessarily lengthy maintenance and servicing operations and rectifications, indicating the holding of an excessive reserve of aircraft.

Further, a reduction in the total man-hours spent in servicing and maintenance would reduce considerably the costs of operation, especially if this saving in man-hours were in the neighbourhood of 50 per cent. which, in the opinion of the writer, could be achieved by design for maintenance.

American aircraft are more easily maintained than British because attention seems to have been paid to this aspect in the design stage. Even so, American aircraft are far from ideal in this respect.

Cowling design and fastenings could be greatly improved upon on nearly all British aircraft, but the writer does not agree with Lt. Bowden that the practice of leaving fasteners undone is general.

There is much that is fragile and easily damaged in careless handling of modern aircraft and improvement could be made in the layout and positioning of such items, especially in cockpits, crew stations and interiors. Competent supervision of maintenance staffs will also help to eliminate damage by inexperienced or careless workers. The writer is not of the opinion that indiscriminate strengthening is the solution to this problem.

Accessibility for servicing on most British aircraft is extremely bad. Further examples in support of Lt. Bowden's plea could be quoted at great length.

It is thought that Lt. Bowden's experiences with aileron changes are unique and the suggestion is that the fault might be other than a manufacturer's error, although such errors do exist. The writer recalls the difficulty once experienced in the fitting of a replacement flap to a certain aircraft. After a thorough investigation it was discovered that a mainplane dimensional error of some 1½ inches had "crept in" during manufacture. The flap gap had been adjusted by a large wooden insert and the flap operating jacks had been set in a manner to suit!

Some analysis of the more lengthy operations of servicing, maintenance and rectification might have been given, together with suggestions for improvement through design for maintenance.

The majority of these difficulties seem to be centred around the installation of power plants and accessories. The layout of many British aircraft suggests that power plant accessories, fuel, oil and coolant systems, controls, and the many other items too lengthy to detail but which go with the power plant, are added piecemeal after the production of the aircraft!

Standardisation of many aircraft and power plant accessories would also be a big asset in the production and operation of British aircraft, including such items as: radiators; pipes and unions, and connections; instruments, together with their attachments to aircraft and power plant; tank filling orifices; all types of cocks and valves; all types of filters and cleaners; ignition harnesses, together with spark plug connectors (and the spark plugs to take them).

Some items which present unnecessary difficulties but ought to meet the following requirements of the mechanic are: accessible fuel and oil filters which do not deposit their contents either on the mechanic or in the engine nacelle; design of fuel, oil, coolant and hydraulic systems to permit the inspection or replacement of any joint or pipe. The replacement of a joint or pipe on a British aircraft invariably presents many unnecessary difficulties together with hours of labour. The writer recalls a light alloy refuelling pipe built into the stub plane of a certain aircraft and which on the majority of aircraft of that type had become unserviceable through corrosion. After many laborious hours of work with spanners in remote corners, the ends were disconnected. The pipe had then to be sawn up to get it out, and it was not possible to fit a replacement!

Such items as control cables, pulleys, distant reading instruments, ignition switch leads,

and so on, should be installed with a view to their possible replacement, caused by defect. Many aircraft constructors seem to think that these items cannot possibly become defective and build them into the aircraft.

Many fairings often cover vital parts and these appear to be built never to come off. As an instance, coolant fluid may be seen to come from a radiator fairing. The only means of inspection and rectification is to remove the fairing in order to have access to the radiator and its connections, and this will probably be a two-day task. Such fairings are invariably badly fitted in the first instance and are usually secured by a large number of inaccessible B.A. screws or bolts. Replacement is the worst as it will probably be found that the multitude of holes do not line up and a file tang does not improve matters!

The writer has not experienced undue difficulty with the aircraft maintenance equipment supplied by aircraft manufacturers, although much of it could be improved. The question of more general tools is worthy of review. A badly designed and cheap set of tools is false economy, since a task can be performed in shorter time with good tools, and the possibility of damage to aircraft parts and fixings would be less. Many tools used by aircraft mechanics to-day were designed before aeroplanes were built, and an inaccessible part may be removed with a hammer and screwdriver for want of the proper tools.

Lt. Bowden's concluding remarks are agreed with and it is maintained that the resulting reduction in operating costs, and the more efficient operation resulting, would more than cover the increased cost of design and production.

Laurance V. Brown, Associate Fellow.

I endorse much of what Lt. Bowden has said about maintenance difficulties, but I am unable to agree with some of his suggestions. It should always be borne in mind that accessibility is largely a governing factor in reliability.

Most units doing major inspections find it essential to keep each aircraft's individual cowlings with the aircraft. I do not think there is a great deal wrong with the present cowling button. It is sufficiently robust, positive and can be repaired fairly easily. The main trouble is that interchangeability is bad. It is a good thing to "tailor" the cowlings of a new aircraft until they do fit. Frequently the sheet to which the buttons are fitted is too flexible and, after usage, they cease to be perpendicular to the surface. Excessive size of cowlings may cause some trouble but small square cowlings can be as difficult as any. A little experimenting on the sequence of doing up buttons is often helpful. I do not think that American cowlings are any better than ours and I doubt if there is any one cause for the trouble. If cowlings are to fit better and air leaks be reduced, there must be closer tolerances all round. The wire rope method is good for radial cowlings. Wing mats should always be used and maintenance and refuelling should be done in rubber-soled shoes.

The interchangeability of major components is lamentable. I have seen eight tailplanes tried before one was found to fit. The answer is to leave as many holes as possible to be drilled in position and to concentrate on the interchangeability of the main fittings. The method of fitting main components by means of a large number of small bolts passing through two flanges is asking for trouble, unless the jigging is accurate. It is important to give the man in the field a bit of scope in order to reduce the time taken and save "foe-stressing," distortion and elongation of holes. I have even seen a fresh set of rivet holes drilled with less than $\frac{1}{8}$ in. of metal between them and the original holes. One of the big troubles

in changing a major component is that it is difficult to forecast the time required as two days may be spent entering some of the bolts.

Engine accessibility leaves much to be desired. Carburettor changes are a work of art and it is frequently necessary to sling an engine out of the bearers to change a starter or a generator. It is often a difficult matter to decide what is the quickest approach. In spite of this, many units would be prepared to spend an extra day or two on changing components rather than get the engine running times out of step by doing an engine change. It is difficult to make constructive suggestions, but I think it is a good start to put the magnetos on the front of the engine. This makes both the harness and the magnetos much more accessible. I think it would be a good idea to fit all the auxiliaries on a gear box some distance away from the engine. If the distance is satisfactory and the new location is good, the frequent changing of these items might be greatly eased and the accessibility of the carburettor, controls, and so on, could be much improved. It is also important to watch any drives that may break. In many installations if the generator drive breaks it can hammer the C.S.U. control conduit and I have known an aircraft come in to land with one engine in coarse pitch while the only defect it need have had was one generator out of action.

Hydraulic troubles can be obscure and difficult to trace, especially where access is difficult and the system complex. If the manufacturers could circularise any wrinkles they have learned by hard experience these would be a great help. For instance, I remember a leak of pressure occurring on two aircraft which was found hard to trace. The manufacturers were able to inform us that the jack casings could distort in mid-stroke, so producing a flight leak which would not show up on ground checks. Simplification of systems would undoubtedly speed up snag hunting and ease maintenance, but I doubt if replacement by mechanical devices would reduce maintenance, although it might increase reliability. It is essential that hydraulic fluids be standardised on all aircraft. Any manufacturer who "flows his own furrow" in this respect must expect that someone at sometime will fill up with the wrong oil and he must be prepared for the consequences.

I endorse Lt. Bowden's plea for avoidance of special threads and wonder whether this could be extended to out-of-the-way sizes and possibly even to locking devices that cannot be used twice. When the "stores bloke" says, "we ain't got none" they are frequently used twice and sometimes he is not even consulted. If odd sizes must be used in places where maintenance or repair is possible, operators should be specially notified so that they may stock up.

It is difficult to see what the designer is expected to do in order to prevent bits falling in places where they are out of sight and out of mind. There are a number of jobs which maintenance people always seem to have to sit in the pilot's seat to do. Undoubtedly a good decking under the main crew positions is a great advantage. A fully decked aircraft, like a Dakota, is an advantage and no doubt this can be done on many transport aircraft. The problem is an important one. I had to ground the Hurricane aircraft in Madagascar and Mauritius while we collected A.G.S. "spares" from the mainland—after a query on a possible stiffening of controls.

I have seen large items in undercarriage wells right the way up to a 2 lb. hammer, and I have seen a Catalina keel plate completely corroded through by orange peel. Many of these things are matters of crew and maintenance cleanliness, but designers can help. Ammunition clips and so on are things which often cause trouble. I would like to see the top pocket ripped out of every suit of overalls.

One could go on in this strain almost indefinitely but I think it is wrong to believe that design staffs send these things just to try us. All people responsible for maintenance schedules would do well to remember that it is not laid down in the Ten Commandments that certain things must be done on minors. In particular, please delete any maintenance where a part is unlikely to give trouble if left alone. My main trouble-shooting method has always been to enquire what was touched last and then go straight to that. There is a difference between looking for and asking for trouble. Many components are almost fool-proof and in some cases duplicated. As far as possible they should be run untouched to major inspection and then changed.

No remarks on maintenance would be complete without some word on modifications. Far too many are issued and far too many that are issued are in the wrong class. Essential and urgent modifications are all too frequently lost in files of Class II modifications that should not even have been issued. It is no use passing everything on as urgent modifications just in case there is a come-back nor is it any use inventing new sub-sub-classes if everything has got to be done anyway. The obvious thing usually happens. Maintenance men have not enough time to do them all, supply systems become overloaded and slow, and a matter of great importance becomes the subject of beautiful technicolour charts, magnificent monthly returns and despair and despondency for all who try and do what is necessary as quickly as possible.

There is no doubt that all these matters can be investigated to great advantage, but I feel it would be wrong to consider them only from the maintenance point of view. Undoubtedly they have a great effect on performance. We all know of the decrease in top speed as an aircraft gets older. What of the effect on rate of climb, stalling speed, single engine performance and manœuvrability? What of the other effects likely to be found in high speed flight?

M. J. Kemper, M.B.E., Associate.

As an ex-Air Engineer Officer in the R.N.V.R., many of the points in Lt. Bowden's article remind me of difficulties that once were only too familiar, but I cannot help feeling that they are characteristic essentially of military aircraft.

Who, for example, would concur with the view that the piston engine is "rapidly becoming extinct"? From the military viewpoint it is becoming *obsolescent*, but from the general aeronautical viewpoint it is still a vital power mechanism. What we are likely to see in the future is a multiplicity of power units serving widely different purposes—reciprocating units, rotary units, rocket units and many combinations of these. This raises the question of specialisation or a higher standard of training for the maintenance engineer. I believe that the latter is preferable.

The question of inaccessibility on military aircraft is the one factor to deter the ground personnel—even if everything else should be satisfactory! Some inconvenience here must be accepted, since maximum speed and strength considerations must dominate the picture at the present. When we (and others!) have progressed to the state of making our contribution to an International Air Police Force we may expect maintenance considerations to assume a more dominant position. Let us hope that this time is not far distant.

S. W. Greenwood, Student, R.Ae.S.

I would like to add two points to Lt. Bowden's paper which he has not mentioned, and to query one other.

Firstly, the use of split pins as a method of locking nuts. This gives a positive locking

but their removal, especially when working in a not easily accessible place, is often difficult. A tap washer shaped to fit in a key way in the bolt and bent up when the nut is tightened would be as efficient.

Secondly, aircraft handling is a great problem. I have come across types of aircraft on which the standard tail arm will not fit. This makes it necessary to manufacture a tail arm for each specific type from local resources.

Although I agree that hydraulic systems are complicated and far from perfect, I do not subscribe to the view that the substitution of mechanical operation would be wise. Admittedly it is a good thing from the maintenance point of view, but it places a greater strain on the pilot if he has to, say, lower the flaps, undercarriage, tailwheel, and so on, by mechanical means as opposed to merely pressing a button or operating a lever. The possibility of the system failing is generally provided for by some form of emergency gear.

By all means have more active co-operation between the design and maintenance people, but let us not forget the pilots, who have a good right to air their suggestions.

D. G. Plowright, Graduate, I.Mech.E., Graduate, R.Ae.S.
(Ex S/Lt. (A/E) R.N.V.R.)

Modern power-plant developments and the ever-increasing speeds at which service aircraft are required to fly will continue to lead toward stiffer aircraft structures. Except in special cases, fabric covering of structures has given way to metal skinning. Where once 24 S.W.G. skins were adequate, skins of 10 S.W.G. or thicker are often used to-day. Future developments will lie in the direction of pure monocoque construction. Wing skins, for example, will probably be machined from $\frac{1}{2}$ inch light alloy plate, or thicker.

This happy tendency is offset to a large extent by the fact that, for aerodynamic reasons, the shape and surface finish of aircraft are, in turn, becoming much more critical. The case quoted by Lt. Bowden, to prove another point, of ailerons which have to be changed a dozen times before correct trim is obtained, can also be used to show how kindly modern aircraft parts must be treated by maintenance men to avoid any distortion, and consequent trouble, in flight.

The problem of cowls, doors, and so on, which, when removed, blow about and are bent or buckled, is being solved by the use of hinges which make removal of these parts from the airframe unnecessary for normal servicing and, in future, it seems that arrangements must be made for suitable storage of any parts which are taken off an aircraft.

Recent official stressing requirements formulated to cover the "crash" case have resulted in a general stiffening of mountings for equipment, seats, and so on.

There appears to be little excuse for service personnel climbing about in heavy boots on combat aircraft. It is surely easier, quicker and more sensible to design and issue a special type of soft-soled, flat-heeled footwear—laced up to the knee if necessary—for the use of ground crews on duty, than for aircraft to be "built like battleships."

In addition, there is an ever-decreasing need for aircraft to be manhandled—even naval machines. Aircraft are becoming more compact. Engine starting, wing folding, and so on, are accomplished by pressing buttons in the pilot's cockpit. "Jeeps" have been provided for shifting aircraft on the flight deck, although it may be difficult to use these in some cases.

With the stiffer structures previously mentioned, it is likely that there will be fewer panels bearing notices six inches high, "Do Not Push Here," but it will always be necessary to apply jacks, trestles, and so on, to an airframe at the proper places provided, and suitably indicated.

It does seem that more attention may have to be paid at the mock-up stage to the provision of suitable hand-holes, and so on, in airframes, and that service personnel may have to be trained to use more elaborate ground equipment.

Official departments can be of great help to all concerned by facilitating visits of design staff members to carriers and service aerodromes. These visits will give them a better understanding of maintenance problems and, incidentally, more interest in their work. Also, the official bodies may be able to help by ensuring that there is always at least one real, one hundred per cent. maintenance man at every major mock-up conference.

Basically, it seems clear that the ground handling of aircraft and aircraft parts must be made a skilled man's job—a "labour of love," not just *labour*.

Edmund W. Coates, Dip.Ae.(Hull), G.I.Mech.E., Assoc. Fellow.

The subject raised by Lt. Bowden is of particular interest and its publication is most timely. I agree most strongly that much more thought should be given now to the easing of servicing problems, some of which have become intolerable.

The fighting services, in common with others, are desperately short of man-power. Much is being done to alleviate these deficiencies, yet much more could be done if the needs of the operators had received more consideration in the design stage of an aircraft. I join in asking for the co-operation of all aircraft firms and for the setting up of machinery to ensure that the service engineer's needs receive the attention they merit.

The efficiency achieved by the services during the war is striking when the semi-skilled people who were called upon to service aeroplanes and the many problems which faced them are considered. The services now have to face up to the employment of N.S.A. entrants and these entrants must be used on aircraft servicing if we are to meet our tasks. Therefore, the problem of servicing aircraft facing the fighting services is now greater than ever and can only be alleviated if servicing tasks are made more easy.

The difficulties of servicing as given by Lt. Bowden are by no means exhaustive and I would like to stress the importance of the following:—

(*a*) If we must bury engines and fuel tanks in mainplanes and fuselages, then means of splitting these major components, in a matter of minutes, should be provided. In this connection attention is drawn to the American Republic Thunder-jet. By means of splitting the fuselage it is claimed that a power plant change can be effected in 50 minutes. With comparable British aircraft it takes longer to remove cowlings and lay bare the power plant than it does to effect the actual power plant change. Is it possible for our designers to arrange for major components to be split and also to provide quick cowling fasteners capable of withstanding the stresses experienced in modern aircraft?

(*b*) Recently a single-seater aircraft with a remarkable performance was produced. The servicing difficulties encountered in this aircraft were very great; the engines were enclosed in such small spaces that the compact design made access to auxiliaries difficult and led to many troubles because of the chafing of pipes. If aerodynamic considerations make such compact design essential, then auxiliaries should be so designed to run without attention for the overhaul life of the engine.

(*c*) Most instruments are held in position by nuts and bolts, often requiring, because of their position, two men to effect a replacement. Yet the introduction of Anchor nuts would do away with the services of one man and would speed up the job.

(*d*) Much time is wasted and difficulty often experienced through having to make individual connections of electrical leads to instruments, particularly in .multi-engined aircraft. This often entails tracing particular leads to their sources. With the wider use of plugs and sockets designed to fit in one position only, the saving in servicing time would be enormous and would also provide a safeguard against making faulty connections.

(*e*) One aircraft in service calls for the auxiliary gear-box to be replenished daily, yet the box is most inaccessible. This one job takes at least half an hour and so is quite unacceptable as a daily routine.

(*f*) With the introduction of two or more turbines in one engine some new method of checking turbine blade clearance will be essential. Can some scheme be devised with quick and accurate servicing as the aim?

(*g*) The removal of jet pipes is a long and difficult process; cannot some quick attachment be devised?

This list of difficulties comes to an end, not because of shortage of examples, but rather from a hope that the difficulties facing the service engineer have now been made clear. Furthermore, it is always too easy to be destructive and that is not my aim.

On the contrary, I merely wish to endorse the statements made by Lt. Bowden and hope that some means of satisfying his complaints may be evolved.

Group Capt. W. R. Worstall, O.B.E., Assoc. Fellow.

Having spent most of my time overseas, where equipment was short and spares few, I have been in a position where improvisation for maintenance has been essential. A considerable proportion of maintenance could be reduced if designers knew the conditions under which their aircraft were going to operate, such as climate and weather; also, the nature of the surface of runways and the dust that is churned up by the aircraft and dust carried in the wind.

One of the problems that has always been a source of trouble is oil tanks. Between the cowling and oil tank filler cap there is usually a fair-sized gap. With some aircraft a special funnel or long-nosed can is necessary for topping up. When the gap is small another evil is the filler cap which is hinged-on and will not open sufficiently to allow the spout of a can to enter completely the oil tank. Working in the open, the slightest breeze blows oil on to the outside of the tank and all over the cowlings. On twin-engined aircraft the oil, more often than not, runs into the mainplane and down the undercarriage; then dust from dry runways sticks to this oil, sticking up undercarriage locks, the undercarriage jack piston rod, electric micro switches and, by no means the least important, the exposed portion of the oleo legs. A leaky oil cap also allows oil to leak on to the above parts, but also supplies enough oil to enter the brakes when the aircraft is flying and wheels retracted. On one type of aircraft the oil spills when topping up, damages the self-sealing rubber tanks, and in one squadron I was with, as spares were not available, all our aircraft were flying with damage to the self-sealing rubber tanks caused by oil. A funnel-shaped shroud between tank and cowling with a drain pipe would eliminate all this trouble.

With petrol tanks a rubber shroud is often fitted between the mainplane and tank filler cap and a drain pipe of an eighth or three-sixteenths of an inch internal diameter. This system is good, but the drain is often too small to prevent petrol from going on to the mainplane. With aircraft darkly coloured and dispersed in the sun, mainplanes often became

too hot even to touch and the rubber shroud soon perished and leaked; replacement was only practicable by removing the tanks. This meant that once the rubber shroud had perished, petrol entered the mainplanes until there was reason to remove the tanks.

One of the leading fighter aeroplanes during the war had a small petrol filler cap. This made refuelling difficult and, with four gallon cans and through a chamois leather, it was slow—often taking a fitter as long to refuel as the aircraft was in the air. Any fuel spilled ran into the fuselage and cockpit. With the heat from the sun, this resulted in several accidents. After refuelling, cockpits had to be left open to prevent collection of petrol fumes.

Oil and petrol filters are mostly inaccessible on compact installations. If there is any foreign matter in the filter, it is more often than not spilled or wiped off on some part before the filter is clear of the installation. In sandy or dusty places these filters have to be removed after every flight.

Most engines will eat sand or dust without clogging up the induction system or flame traps, but the air or mixture going to boost control units carries enough dust to choke the unit, and filters that have been fitted between superchargers and boost units have been inadequate. In Sicily at one time, dust penetration into boost units meant they had to be removed, stripped and cleaned daily. This is a great hindrance to an operational unit.

Sand has a habit of building up what may be called a clinker on sparking plugs which prevents them from firing. I have often seen this a quarter of an inch thick, but it varies according to the position of the cylinder. Home-made air filters were fitted that were jettisoned after take-off, but landing and low flying still caused the above troubles.

At Araxos (Greece), few aircraft made five landings without having to have their tyres changed. This was caused by the bad runway surface. Heavy aircraft had to be jacked up on rough ground with jacks that had to be pulled along on metal wheels a few inches in diameter. These wheels were not big enough and gave the jacks a good shaking up, causing continuous maintenance for the jacks. Bolts in the aircraft wheels were split-pinned where wire safety pins could have been used and reduced time considerably.

Engine auxiliaries are very inaccessible. Often a gear box is fitted to the bulkhead with auxiliaries on both sides. On one aircraft the oil system had to be drained and the oil tank removed to reach the compressor. In dusty climates, where air compressors give their fair share of trouble, I think layout could be improved.

With shortage of spares, an aircraft that becomes unserviceable soon becomes a "christmas tree" and is robbed of nearly everything.

Fitting hoods, hatch doors and especially cowlings from one aircraft to another is an art that has to be acquired, although the parts are supposed to be identical.

Accumulators are a source of danger, even the non-spill types spill and boil over. I can never understand why accumulators are positioned as they are in aircraft, although there may be reasons. Next to the main spar, on boiling over they cover the spar with acid, causing damage to a part that cannot have a temporary repair. Other cases are above engine bearers and so the bearers are soon corroding.

I know one aircraft that covers the starboard undercarriage up-lock with acid every time the accumulator spills. This, besides causing additional maintenance, is a constant danger to air crew.

S. W. Thomas, Student.

AN APPRECIATION

The Council of the Royal Aeronautical Society wish to thank those Companies who, by their generous co-operation, have done so much to help in the production of the Journal

ACCLES & POLLOCK LIMITED

A&P
Make it with Tubes

AIRWORK LIMITED

AIRWORK
LIMITED

AEROPLANE & MOTOR ALUMINIUM CASTINGS LTD.

ALUMINIUM CASTINGS

ALVIS LIMITED

ALVIS

AIRCRAFT MATERIALS LIMITED

AML
STRUCTURAL MATERIALS
and COMPONENTS

ARMSTRONG SIDDELEY MOTORS LTD.

ARMSTRONG SIDDELEY

AIRSPEED LIMITED

AIRSPEED

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LTD.

SIR W. G.
ARMSTRONG WHITWORTH
AIRCRAFT LIMITED

AUSTER AIRCRAFT LIMITED

T. M. BIRKETT & SONS LTD.

NON-FERROUS CASTINGS
AND MACHINED PARTS

HANLEY . . STAFFS

AUTOMOTIVE PRODUCTS COMPANY LTD.

BLACKBURN AIRCRAFT LTD

AVIMO LIMITED

OPTICAL - MECHANICAL - ELECTRICAL INSTRUMENTS
AERONAUTICAL EQUIPMENT

JAMES BOOTH & COMPANY LTD.

BAKELITE LIMITED

BOULTON PAUL AIRCRAFT LTD.

BIRMINGHAM ALUMINIUM CASTING (1903) CO. LTD.

BRAKE LININGS LIMITED

THE BRISTOL AEROPLANE CO., LTD.

"Bristol"

BRITISH THOMSON-HOUSTON CO., LIMITED (THE)

B T-H

Magnetos and Electrical Equipment

THE BRITISH ALUMINIUM CO., LTD.

BA

BRITISH WIRE PRODUCTS LTD.

THE BRITISH AVIATION INSURANCE CO. LTD

BRITISH AVIATION SERVICES LTD.

BROOM & WADE LTD.

"BROOMWADE"

AIR COMPRESSORS AND PNEUMATIC TOOLS

BRITISH INSULATED CALLENDER'S CABLES LTD.

B.I. Callender's

BROWN BROTHERS (AIRCRAFT) LTD.

Brown Brothers (AIRCRAFT) Ltd.
CONTROLS · AEROJACKS · A.C.S. · A.S. PARTS

BRITISH OVERSEAS AIRWAYS CORPORATION

B·O·A·C

BUTLERS LIMITED

AUTOMOBILE, AIRCRAFT AND MARITIME LAMPS SEARCHLIGHTS AND MOTOR ACCESSORIES

THE CHLORIDE ELECTRICAL STORAGE CO. LTD

DUNFORD & ELLIOTT (SHEFFIELD) LTD

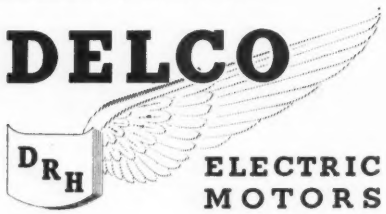
A. C. COSSOR LIMITED

DUNLOP RUBBER CO., LTD.

THE DE HAVILLAND AIRCRAFT COMPANY LTD.

ENGLISH STEEL CORPORATION LTD.

DELCO-REMY & HYATT LTD.



THE FAIREY AVIATION COMPANY LTD.

DOWTY EQUIPMENT LIMITED

FIRTH-VICKERS STAINLESS STEELS LTD.

FOLLAND AIRCRAFT LIMITED

HAMBLE, SOUTHAMPTON

HELLIWELLS LIMITED

GENERAL AIRCRAFT LIMITED

THE HESTON AIRCRAFT CO., LTD.

GLOSTER AIRCRAFT CO., LTD.

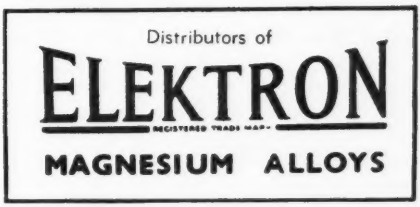
HIGH DUTY ALLOYS LIMITED

HANDLEY PAGE LIMITED

H. M. HOBSON LTD.

HAWKER AIRCRAFT LIMITED

F. A. HUGHES & CO., LIMITED



HENRY HUGHES & SON LTD

INTEGRAL LIMITED

INTEGRAL
HYDRAULIC PUMPS
AND EQUIPMENT

THE HUGHES-JOHNSON STAMPINGS LTD.

IRVING AIR CHUTE OF GREAT BRITAIN LTD

HUNTING AVIATION LIMITED

K.L.G. SPARKING PLUGS LTD.

HYMATIC ENGINEERING CO. LTD.

Hymatic
COMPRESSED AIR EQUIPMENT

KELVIN BOTTOMLEY & BAIRD LTD.

IMPERIAL CHEMICAL INDUSTRIES LTD.

LIGHT-METAL FORGINGS LTD.

LODGE PLUGS LIMITED

LODGE
PLUGS

D. NAPIER & SON LIMITED

MARSTON EXCELSIOR LIMITED

NORMALAIR LIMITED

NORMALAIR

MILES AIRCRAFT LIMITED

Miles
AIRCRAFT

THE PALMER TYRE LIMITED

'First in the Air'

Palmer

THE PALMER TYRE LIMITED
Herga House, Vincent Square, London, S.W.1.

MOLLART ENGINEERING COMPANY LTD.

Members of the Gauge and Tool Makers' Association

PERCIVAL AIRCRAFT LIMITED

THE MOND NICKEL COMPANY LTD

PETO & RADFORD

DAGENITE
AIRCRAFT BATTERIES

PORTSMOUTH AVIATION LIMITED

A. V. ROE & COMPANY LIMITED

PRESSED STEEL CO., LIMITED

PRESTCOLD
Refrigeration

ROLLS-ROYCE LIMITED

ROLLS-ROYCE
AERO-ENGINES

THE PULSOMETER ENGINEERING CO. LTD.

ROTAX LIMITED

ROTAX
AIRCRAFT ELECTRICAL ENGINEERS

QANTAS EMPIRE AIRWAYS

ROTOL LIMITED

R.F.D. COMPANY LTD.

SANGAMO WESTON LTD.

SKYHI LIMITED

SAUNDERS-ROE LIMITED

SMITHS AIRCRAFT INSTRUMENTS LTD.

SERCK RADIATORS LIMITED

THE SPERRY GYROSCOPE COMPANY LTD

SHORT BROTHERS (ROCHESTER & BEDFORD) LIMITED

Shorts

Established 1908

THE FIRST MANUFACTURERS OF AIRCRAFT IN THE WORLD

STRAIGHT AVIATION TRAINING LTD

THE TECHNOLOGICAL INSTITUTE OF GREAT BRITAIN

COURSES FOR THE EXAMINATIONS OF THE ROYAL AERONAUTICAL SOCIETY

A. C. WICKMAN LIMITED

A.C. Wickman LIMITED
• COVENTRY • ENGLAND •
SPECIALISTS IN MACHINE TOOLS & SMALL TOOLS FOR THE AIRCRAFT INDUSTRY

THE UNITED STEEL COMPANIES LIMITED

"FLYING FOX" ELECTRIC STEELS
S. FOX & CO. LTD. SHEFFIELD

HENRY WIGGIN & COMPANY LTD

For High Quality
NICKEL ALLOYS

VOKES LIMITED

AMBER CROSS
TRADE MARK
SYMBOL OF THE VOKES SERVICE

WILLIAMSON MANUFACTURING CO., LTD

WESTLAND AIRCRAFT LIMITED

YORKSHIRE ENGINEERING SUPPLIES LTD.

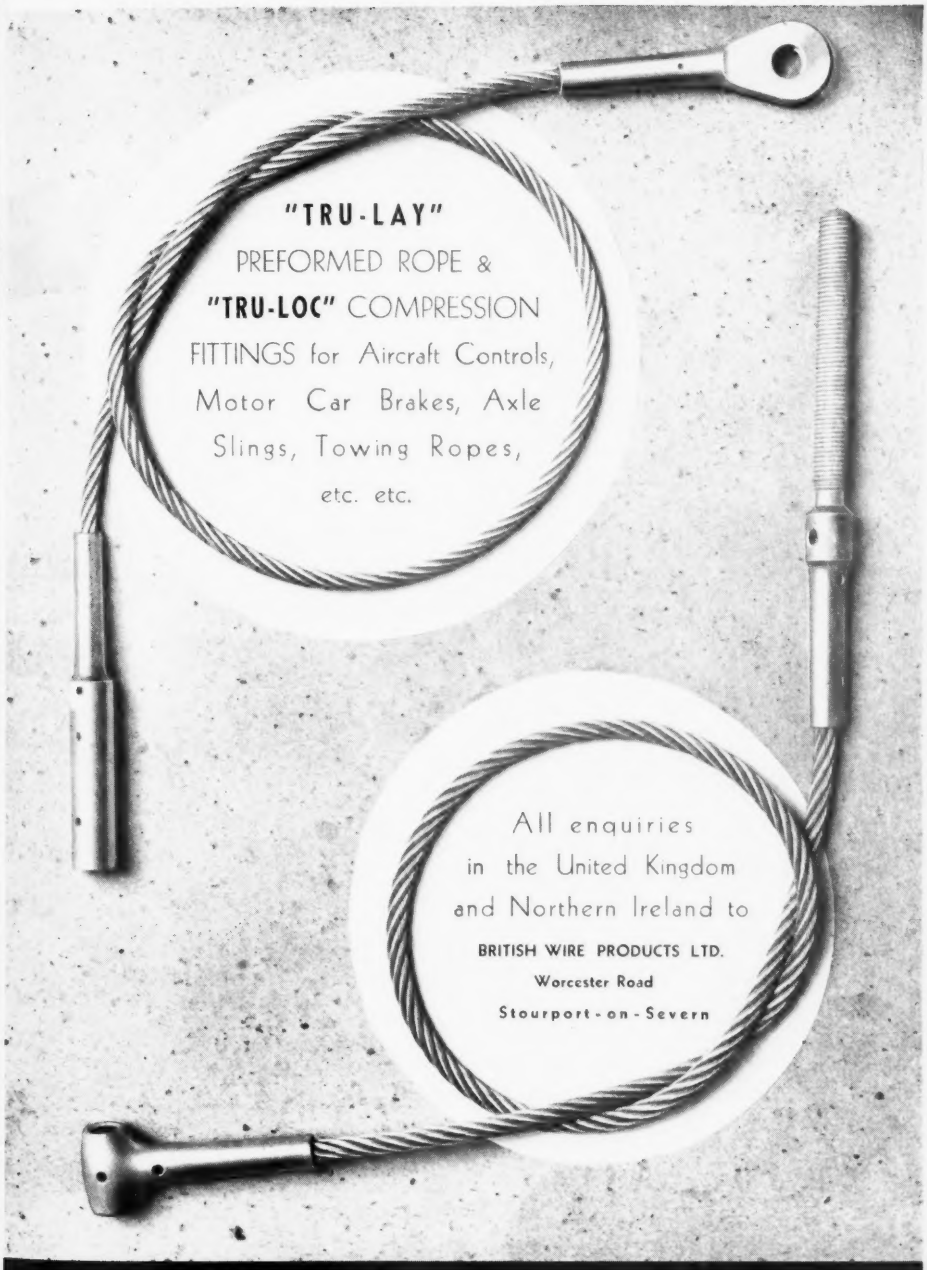
BRONZE FOUNDRIES
YESEATONIA
BEARINGS AND BUSHES

DIRECTORY OF ADVERTISERS

ACCLES & POLLOCK LTD.	Paddock Works, Oldbury, Birmingham	Broadwell 1500
AEROPLANE & MOTOR ALUMINIUM CASTINGS LTD.	Wood Lane, Erdington, Birmingham	Erdington 2207-9
AIRCRAFT MATERIALS LTD.	Midland Road, London, N.W.1.	Euston 6151
AIRSPEED LTD.	The Airport, Portsmouth	Portsmouth 74631
AIRWORK LTD.	15 Chesterfield Street, W.1.	Grosvenor 4841
ALBRIGHT & WILSON	49 Park Lane, W.1. Works: Oldbury and Widnes.	Grosvenor 1311
ALVIS LTD.	Holyhead Road, Coventry	Coventry 5501
ARMSTRONG SIDDELEY MOTORS LTD. ...	Parkside, Coventry	Coventry 4061
ARMSTRONG WHITWORTH AIRCRAFT, SIR W. G., LTD.	Whitley, Coventry	Coventry 61061-4
AUSTER AIRCRAFT LTD.	Britannia Works, Thurmaston, Leicester	Syston 86106-8
AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO. LTD.	Winder House, Douglas Street, S.W.1	Victoria 3404-8
AUTOMOTIVE PRODUCTS CO. LTD.	Tachbrook Road, Leamington Spa	Leamington Spa 1700
AVIMO LTD.	Taunton, Somerset	Taunton 3634
BAKELITE LTD.	18 Grosvenor Gardens, S.W.1	Sloane 9911
BIRKETT, T. M. & SONS LTD.	Thomas Street, Hanley, Stoke-on-Trent	Stoke-on-Trent 2184
BIRMINGHAM ALUMINIUM CASTING (1903) CO. LTD.	Birmid Works, Smethwick, Birmingham 40	Smethwick 1431
BLACKBURN AIRCRAFT LTD.	Brough, E. Yorks	Brough 121
BOOTH, JAMES, & CO. LTD.	Argyle Street Works, Nechells, Birmingham, 7 ...	Birmingham E. 1221
BOULTON PAUL AIRCRAFT LTD.	Wolverhampton, Staffs	Fordhouses 3191
BRAKE LININGS LTD.	Buxton, Derbyshire	Buxton 776
BRISTOL AEROPLANE CO. LTD., THE ...	Filton House, Bristol	
BRITISH ALUMINIUM CO. LTD.	Salisbury House, London Wall, E.C.2	Clerkenwell 3494
BRITISH AVIATION INSURANCE CO. LTD. ...	3-4 Lime Street, E.C.3	Mansion House 0444
BRITISH AVIATION SERVICES LTD.	1 Great Cumberland Place, W.1	Paddington 7040
BRITISH BELTING AND ASBESTOS LTD. ...	Cleckheaton, Yorks.	Cleckheaton 800
	59 Southwark Street, S.E.1	Hop 0192
BRITISH EUROPEAN AIRWAYS CORPORATION	Headquarters: Northolt Airport, Middlesex	Ruislip 6061
BRITISH INSULATED CALLENDAR CABLES LTD.	Main Works: Erith, Helsby, Leigh, Lancs. and Prescot	
BRITISH OVERSEAS AIRWAYS CORPORATION	Headquarters: Airways House, Berkeley Sq., W.1.	Mayfair 8400
	Traffic Enquiries: Airways Terminus, Victoria, S.W.1.	Victoria 2323
BRITISH THOMSON-HOUSTON CO. LTD. ...	Lower Ford Street, Coventry	Coventry 4104
BRITISH WIRE PRODUCTS LTD.	Worcester Road, Stourport-on-Severn	Stourport 240
BROOM & WADE LTD.	High Wycombe, Bucks.	High Wycombe 1630
BROWN BROTHERS (AIRCRAFT) LTD. ...	Great Eastern Street, E.C.2	Bishopsgate 7654
BUTLERS LTD.	Atlantic Works, Grange Road, Small Heath, Birmingham, 10	Victoria 2164-6
CHLORIDE ELECTRICAL STORAGE CO. LTD., THE	Exide Works, Clifton Junction, near Manchester ...	Swinton 2011
COSSOR, A. C. LTD.	Highbury Grove, N.5	Canonbury 1234
DE HAVILLAND AIRCRAFT CO. LTD., THE	Hatfield Aerodrome, Herts.	Hatfield 2345
DELCO-REMY & HYATT LTD.	111 Grosvenor Road, S.W.1	Victoria 6242
DOWTY EQUIPMENT LTD.	Cheltenham, Gloucester	Cheltenham 53471
DUNFORD & ELLIOTT (SHEFFIELD) LTD. ...	Attercliffe Wharf Works, Sheffield, 9	Sheffield 41121-4
DUNLOP RUBBER CO. LTD.	Fort Dunlop, Erdington, Birmingham, 24	Erdington 2121
ENGLISH STEEL CORPORATION LTD.	Vickers Works, Sheffield	Sheffield 41071
FAIREY AVIATION CO. LTD.	Hayes, Middlesex	Hayes 3800
FIRTH, THOS., & JOHN BROWN LTD. ...	Atlas & Norfolk Works, Sheffield, 1	Sheffield 20081, 26401
FIRTH-VICKERS STAINLESS STEELS LTD. ...	Staybrite Works, Sheffield	Sheffield 41193
FOLLAND AIRCRAFT LTD.	Hamble, Southampton, Hants.	Hamble 3191
GENERAL AIRCRAFT LTD.	The London Air Park, Feltham, Middlesex ...	Feltham 3656
GLOSTER AIRCRAFT CO. LTD.	Gloster Works and Aerodrome, Hucclecote, Glos.	Gloucester 6294
HANDLEY PAGE LTD.	Cricklewood, N.W.2	Gladstone 8000
HAWKER AIRCRAFT LTD.	Canbury Park Road, Kingston-on-Thames	Kingston 1044 Slough 23861
HELLIWELLS LTD.	Old Town, Stratford-on-Avon	Stratford-on-Avon 3265
HESTON AIRCRAFT CO. LTD., THE	Heston Airport, Middlesex	Southall 2321
HIGH DUTY ALLOYS LTD.	89 Buckingham Avenue, Slough, Bucks.	Slough 21201
HOBSON, H. M. LTD.	Hobson Works, Stafford Road, Wolverhampton ...	Fordhouses 2266
HUGHES, F. A &. CO. LTD.	Metals Dept., Abbey House, Baker Street, N.W.1	Welbeck 2332-6
HUGHES, HENRY, & SON LTD.	Husun Works, New North Rd., Barkingside, Essex	Hainault 2601
HUGHES-JOHNSON STAMPINGS LTD., THE ...	Langley Green, Birmingham	Broadwell 1361
HUNTING AVIATION LTD.	P.O. Box 4, Caernarvon, N. Wales	Caernarvon 580
HYMATIC ENGINEERING CO. LTD.	Redditch, Worcestershire	Redditch 745

DIRECTORY OF ADVERTISERS

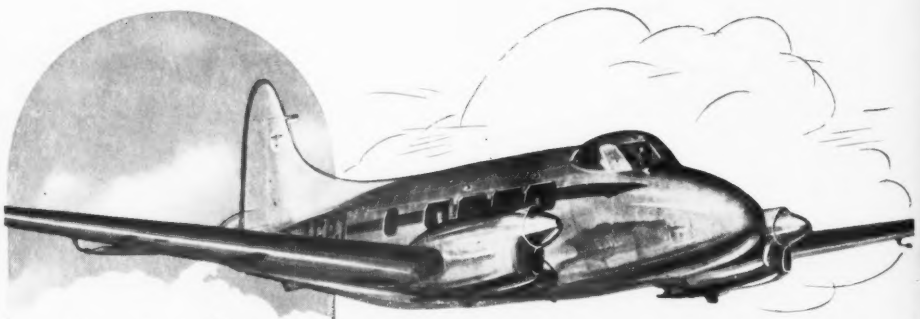
Iliffe and Sons Ltd.	Dorset House, Stamford Street, S.E.1	Waterloo 3333
Imperial Chemical Industries Ltd.	London, S.W.1	Victoria 4444
Integral Ltd.	Cousins Street, Dudley Road, Wolverhampton	Wolverhampton 24984-5
Irving Air Chute of Great Britain Ltd.	Ickneild Way, Letchworth, Herts.	Letchworth 888
K.L.G. Sparking Plugs Ltd.	Putney Vale, S.W.15	Putney 2671
Kelvin, Bottomley & Baird Ltd.	Kelvin Avenue, Hillington, Glasgow, S.W.2	Halfway 3331
	Kelvin Works, Basingstoke	Basingstoke 690
Light-Metal Forgings Ltd.	Oldbury, Birmingham	Broadwell 1152
Lodge Plugs Ltd.	Rugby	Rugby 2076
Marston Excelsior Ltd.	Wolverhampton	Wolverhampton 21481
	49-59 Armley Road, Leeds, 12	Armley 38081-5
Miles Aircraft Limited	Reading, Berkshire	Reading 60811
Mollart Engineering Co. Ltd.	Kingston By-Pass, Surbiton, Surrey	Elmbridge 3352-4
Mond Nickel Co. Ltd., The	Grosvenor House, Park Lane, W.1	Grosvenor 4131
Napier, D., & Son Ltd.	Acton, W.3	Shepherds Bush 1220
Normalair Ltd.	West Hendford, Yeovil, Somerset	Yeovil 1100
Palmer Tyre Ltd., The	Herga House, Vincent Square, S.W.1	Victoria 8323
Percival Aircraft Ltd.	Luton Airport, Luton, Beds.	Luton 2960
Peto & Radford	Chequers Lane, Dagenham, Essex	Rainham 34
Pitman, Sir Isaac, & Sons Ltd.	Parker Street, Kingsway, W.C.2	Holborn 9791
Portsmouth Aviation Ltd.	The Airport, Portsmouth	Portsmouth 74374
Pressed Steel Co. Ltd.	Cowley, Oxford	Oxford 77701
Pulsometer Engineering Co. Ltd., The	Nine Ems Iron Works, Reading: 39 Victoria Street, S.W.1	Tilehurst 67182-4
Qantas Empire Airways	c/o British Overseas Airways Corporation, Airways Terminal, Buckingham Palace Road, S.W.1	Victoria 3126
R.F.D. Company Ltd.	Stoke Road, Guildford, Surrey	Guildford 3232
Roe, A. V., & Co. Ltd.	Newton Heath, Manchester	Failsworth 2020
Rolls-Royce Ltd.	Derby	Derby 2424
Rotax Ltd.	Willesden Junction, N.W.10	Elgar 7777
Rotol Ltd.	Cheltenham Road, Gloucester	Gloucester 4431
Sangamo Weston Ltd.	Great Cambridge Road, Enfield, Middlesex	Enfield 3434 & 1242
Saunders-Roe Ltd.	40 Parliament Street, Westminster, S.W.1	Whitehall 7271
Serck Radiators Ltd.	Warwick Road, Birmingham, 11	Victoria 0531
Short Brothers (Rochester & Bedford) Ltd.	Rochester, Kent	Chatham 2261
Simmonds Aerocessories Ltd.	Great West Road, Brentford, London	Ealing 2212
Skyhi Ltd.	"Skyhi" Works, Worton Rd., Isleworth, Middlesex	Hounslow 2211
Smiths Aircraft Instruments Ltd.	Cricklewood Works, London, N.W.2	Gladstone 3333
Sperry Gyroscope Co. Ltd., The	Great West Road, Brentford, Middlesex	Ealing 6771
Straight Aviation Training Ltd.	Bush House, Aldwych, W.C.2	Temple Bar 6828
Tecalemit Ltd.	Great West Road, Brentford, Middlesex	Ealing 6661
Technological Institute of Great Britain Ltd., The	39 Temple Bar House, Fleet Street, E.C.4	Central 5940
Temple Press Ltd.	Bowling Green Lane, E.C.1	Terminus 3636
United Steel Companies Ltd., The	17 Westbourne Road, Sheffield, 10	Sheffield 60031
Vokes Ltd.	Henley Park, nr. Guildford, Surrey	Guildford 62861
Westland Aircraft Ltd.	Yeovil	Yeovil 1100
Wickman, A. C., Ltd.	Tile Hill, Coventry	Tile Hill 66271
Wiggin, Henry, & Co. Ltd.	Wiggin Street, Birmingham	Edgbaston 2245
Williamson Manufacturing Co. Ltd.	Litchfield Gardens, Willesden Green, N.W.10	Willesden 0073-0075
Yorkshire Engineering Supplies Ltd.	Bronze F... ...es, Upper Wortley Road, Leeds, 12	Leeds 38234 & 38291



The Trade Marks **"TRU-LAY"** and **"TRU-LOC"** are used for the purpose of indicating that the goods in respect of which they are used are goods complying in all respects with the specifications and directions of the **AMERICAN CHAIN & CABLE COMPANY INC.**, the proprietors of the Trade Marks.

PALMER

First in the AIR!



de Havilland

Dove

equipment includes PALMER SILVO-FLEX high-pressure hose units, B.T.R. De-Icers, etc.*

THE FIRE RISK

**Palmer SILVOFLEX fuel and oil pipes of a new fire-proof type are fitted to de Havilland 'Goblin' and 'Ghost' engines; to Rolls-Royce 'Merlin,' 'Eagle' and 'Griffin,' Napier 'Sabre' and Bristol 'Hercules.' Also to practically all current jet types including Rolls-Royce 'Derwent' (616 m.p.h.), 'Trent' and 'Nene,' Armstrong-Siddeley 'Mamba' and 'Python,' etc.*

SINCE 1913, Palmer has provided unique services for the aircraft industry and for flying in all its phases — design, research, experiment, production.

To-day, Palmer tyres are made for tiny tail wheels and through the whole range of sizes up to giants—as tall as a man—for Lancaster liners. The production of wheels, brakes and hydraulic control systems, including gun-firing gear, was greatly accelerated by war demands and the Company now commands important resources for the fabrication of metal as well as rubber components.

INDUSTRIAL PALMER X-RAY SERVICE

PALMER APPROVED RADIOLOGICAL TEST HOUSE IS NOW AT THE SERVICE OF INDUSTRY . . . . .

THE PALMER TYRE LTD.

HERGA HOUSE, VINCENT SQUARE, LONDON, S.W.1

Printed by the Lewes Press (Wightman & Co., Ltd.), Friars Walk, Lewes, England. and Published by the Royal Aeronautical Society, 4, Hamilton Place, London, W.1, England.

R

rvices
ll its
ction.
heels
nts—
The
ntrol
reatly
now
on of

AL
HE

S.W.1

Royal